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NASA's LONG RANGE PLANS

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HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

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NASA's LONG RANGE PLANS

TUESDAY, SEPTEMBER 17, 1985

House of Representatives,
Committee on Science and Technology,
Subcommittee on Space Science and Applications,
Washington, DC.

The subcommittee met, pursuant to call, at 1:05 p.m., in room 2318, Rayburn House Office Building, Hon. Bill Nelson (chairman of the subcommittee) presiding.

Mr. Nelson. The committee will be in order.

We will proceed on our 2 days of hearings on NASA's long-range plans. This is an area for oversight that is of particular interest to this subcommittee, and we have long advocated that NASA and the administration should formulate a realistic definition of future scientific and national needs. We believe that this type of thinking is crucial to maintaining U.S. leadership in space endeavors.

We are also concerned for NASA as an organization. Any successful large organization, be it in the public or private sector, must constantly plan for the future and anticipate the technological, economical, social, and political changes that will occur. This is a responsibility of top management, and we will hear today from the individuals who are charged with carrying out that responsibility.

Now, to a great extent, long-range planning is a process of merging priorities. Today, in this hearing we are going to focus on both the management approach and the results of this process. We also want to examine the impacts that these plans may have on the resources and the institutional character of NASA.

For our part, we, as a subcommittee, are also planning for the future. These hearings will assist us in placing our future oversight and authorization activities in a clear perspective. We want NASA's testimony to serve as a benchmark by which we can assess our progress toward attaining our national goals in space over the next decade.

Notwithstanding the need and benefits of long-range planning, which we will talk about today, I recognize that our system of government provides for a constant reassessment which many times defeat such well-intentioned plans. Thus, there is also the need as we plan for the future for flexibility and skill as we adjust our decisions for the future.

I want to take this opportunity to commend NASA for one notable example of flexibility and playing catchup ball that will have a major impact in the near term. I speak of the recent success of the International Cometary Explorer which returned a bounty of data on the Comet Giacobini-Zinner. This feat has had the effect of positioning the United States in the lead role despite the decision not to mount a mission to Halley's Comet. And I congratulate you all for an extraordinarily successful scientific mission and mission planning. My hat is off to you.

I had an interesting meeting last week. I met with the eminent Soviet scientist Dr. Roald Sagdeev, and his enthusiasm over the Giacobini-Zinner success was clearly evident. In October, I will be leading a delegation to the Soviet Union, which Mr. Moore will accompany us, to meet with Dr. Sagdeev and other Soviet officials to discuss future cooperative efforts in space. Today's hearings will be of great value in understanding the scope of future activities that may be candidates for such cooperation.

Today, we are going to hear from Jim Beggs, NASA Administrator, who will give us an overview of NASA's long-range plans, and he will be followed by the Associate Administrators for space station, for space flight, and for aeronautics and space technology, who will provide more detail.

And I am mindful of Mr. Beggs' time constraint, and therefore we will proceed on that basis.

And we will enter for the record the statement of Mr. Walker, my ranking member.

[The prepared opening of Mr. Walker follows:]

OPENING REMARKS OF
REPRESENTATIVE ROBERT S. WALKER
THE NASA TEN YEAR PLAN
SEPTEMBER 17, 1985

GOOD AFTERNOON, MR. CHAIRMAN. I WOULD LIKE TO JOIN YOU IN WELCOMING OUR WITNESSES HERE TODAY. THESE SESSIONS ON LONG-RANGE PLANS ARE AMONG THE MOST IMPORTANT HEARINGS WE HOLD ALL YEAR.

I WOULD LIKE TO ECHO THE CHAIRMAN'S CONCERNS ABOUT NASA AS AN INSTITUTION. WE FORESEE SOME LEAN BUDGETARY YEARS WHICH WILL DRIVE SOME VERY DIFFICULT PROGRAM DECISIONS. SOME PROGRAMS WILL REQUIRE LARGE AMOUNTS OF MONEY MERELY TO REMAIN EVEN. OTHERS, PARTICULARLY PROPOSED NEW STARTS, WILL BE EXTREMELY SENSITIVE TO FUNDING LEVELS.

OURS IS A SYSTEM IN WHICH THE PRESIDENT PROPOSES AND THE CONGRESS DISPOSES. EACH YEAR THE BUDGET COMES UP FOR OUR REVIEW AND APPROVAL.

HISTORICALLY THERE HAS BEEN REMARKABLE AGREEMENT BETWEEN NASA AND THE CONGRESS ON THE MANNER IN WHICH OUR SPACE PROGRAM SHOULD BE CONDUCTED. IN LARGE PART THIS HAS BEEN BECAUSE THIS PROGRAM IS APOLITICAL AND HAS STRONG BIPARTISAN SUPPORT. WE SEE THAT TRADITION CONTINUING IN THE FUTURE.

However, I must say that I see the role of this committee as one in which we review critically the short and long-term goals of the agency. We want to ensure that the space program adequately addresses the appropriate scientific, economic and political policies of the United States.

As the Chairman has said, long-term management is, in essence, a process of continual balancing of priorities and allocation of scarce financial and personnel resources. Our review of the ten-year plan helps us to assess how that process is working within the agency.

Finally, Mr. Chairman, let me again congratulate you on your selection to fly as a mission specialist on an upcoming shuttle flight. I would like to point out to the Administrator that this committee is unusual in that we do almost everything in a strongly bipartisan way. However, Mr. Administrator, you should know that as the Ranking Republican on the Space Science and Applications Subcommittee I generally follow my Chairman's lead, but, as a matter of policy, I give no one my proxy, even in oversight activities.

Mr. NELSON. So, Mr. Beggs, please proceed.

STATEMENT OF HON. JAMES M. BEGGS, ADMINISTRATOR, NASA, WASHINGTON, DC

Mr. BEGGS. Thank you, Mr. Chairman.

Mr. Chairman, I appreciate this opportunity to discuss with you NASA's long-range planning and to provide an introduction to the briefings which will follow by each of NASA's program associate administrators.

Because of the long leadtime required for conceiving and developing NASA's projects and because many of these projects operate for many years, effective planning and a strong technical capability in terms of people and facilities are of great importance. The wide diversity of the scientific and technical efforts we serve reinforces the need for careful planning to ensure that the resulting program is balanced. Experience has taught us that we must look ahead 10 to 20 years, and sometimes beyond.

NASA's planning process begins annually with a review by NASA management of proposed programs for the prospective year and later years. These program proposals are refined with the assistance of Center management and NASA's advisory committee structure. This process is of great value not only for setting forth goals and policy on a continuing basis, but also for providing a measure of progress in fulfilling NASA's overall mission.

I commend the committee for its interest in the long-range planning of the agency, and, in particular, for creating the National Commission on Space. In its report to the President and the Congress next year, the Commission will provide a comprehensive analysis of program and policy options which will inform NASA's planning for entering the next century.

I have been asked before by members of this subcommittee about where I see NASA in 25 years. Let me take the opportunity to offer my ideas.

Within a decade, we'll be operating permanently in space. Our base will be the space station we are beginning to develop with our friends in Canada, Europe, and Japan. The space station and the new technologies and discoveries that will come with it will expand the peaceful uses of space and their applications to an extent we can hardly imagine today. This expansion will be far reaching and will include a wide variety of scientific, commercial and technological endeavors. Most important, it will assure U.S. leadership in space through the end of this century and well into the next.

With such a permanent base in space, we will also be able to reach, retrieve, maintain, and repair such important satellites as the Hubble Space Telescope. The space station will give us a permanent laboratory on orbit where Government and industry, working in partnership, will do microgravity research, a necessary precursor to new products and new manufacturing technologies. The space station will also open the door for future, more ambitious missions. We expect by the year 2000 the station and its associated platforms will be equipped with a supporting infrastructure that will enable us to operate routinely, both at low Earth and geostationary orbits as well as between them and, eventually, at distances as far as the Moon and the inner planets.

At the same time, we will continue to build upon our major successes in space science and in the applications of space technology. In astronomy and astrophysics, we will build upon our early achievements to enter the era of the great observatories. The path to this future is being defined even now in the Hubble Telescope and Gamma Ray Observatory and in planning for the Advanced X-Ray Astrophysics Facility and the Space Infrared Telescope Facility.

In the field of planetary exploration, we have a unique opportunity to continue our systematic exploration of the planets and primitive bodies in the vicinity of the Sun. Following the carefully constructed program strategy laid out by the Solar System Exploration Committee, the coming decades should provide us with our first close encounters with asteroids and comets and more intensive investigations of the inner and outer planets.

Looking further to the future, we will no doubt return to Mars, our nearest neighboring planet, with rovers, sample returns; and in the longer range, perhaps, a manned mission to extend the human reach to another planet for the first time.

We will not ignore the exploration of our own planet. The ability to transport, assemble and maintain observational tools in orbit will enable whole new classes of instruments for atmospheric, geological, and other scientific observations. When coupled with the increasingly powerful computational tools and the emerging interdisciplinary research programs, we will be able to lay the groundwork for a truly unified Earth science of enormous practical value. In this regard, the Advanced Earth Observing System to fly on the polar platform of the space station in the midnineties will provide major enhancements to our capabilities for remote-sensing of conditions on Earth.

As we look to the future we will have to think about ways to overcome size and weight constraints on what we can put into space. Sometime before the year 2000 we will probably need a new heavy-lift, unmanned launch capability to orbit objects that are larger and weigh more than we can orbit today.

By the same token, we would probably want to construct a new generation of shuttles, smaller, lighter, more flexible and less expensive to operate than the present generation of multipurpose vehicles.

Advanced technology provides the underpinning for these and other future space missions and is an essential ingredient to our continued preeminence in space. Enabling technologies for air-breathing-to-orbit transatmospheric vehicles and other low cost transportation systems; smart, telerobotic systems; and large power systems are but a few of the high payoff areas we are pursuing in our Space Research and Technology Program.

"Humanity is just a work in progress," wrote Tennessee Williams. Indeed we are. And as we evolve and grow, I believe we will demonstrate that there are no limits to our future in the universe.

That concludes my prepared remarks, Mr. Chairman. I would be pleased to respond to questions.

[The prepared statement of Mr. Beggs follows:]

Statement of

James M. Beggs
Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I appreciate this opportunity to discuss with you NASA's long-range planning and to provide an introduction to the briefings which will follow by each of NASA's program Associate Administrators. These briefings will cover NASA's planning in Space Flight, Space Science and Applications, the Space Station, Space Technology, Space Tracking and Data Systems and institutional considerations.

Because of the long lead-time required for conceiving and developing NASA's projects and because many of these projects operate for many years, effective planning and a strong technical capability in terms of people and facilities are of great importance. The wide diversity of the scientific and technical efforts we serve reinforces the need for careful planning to ensure that the resulting program is balanced. Experience has taught us that we must look ahead 10 to 20 years, and sometimes beyond. Looking out that far is essential not only for creating a framework within which we can plan resources, but also for ensuring that work undertaken in the near term will move us toward achieving long term objectives.

NASA's planning process begins annually with a review by NASA management of proposed programs for the prospective year and later years. These program proposals are refined with the assistance of Center management and NASA's advisory committee structure. The advisory apparatus includes the Boards of the National Academies of Science and Engineering and the Committees of NASA's Advisory Council, as well as leaders in industry, universities and non-governmental research organizations. These examinations underpin program proposals which are formulated as NASA's submission to OMB, and ultimately as the President's budget request for NASA. This process is of great value not only for setting forth goals and policy on a continuing basis, but also for providing a measure of progress in fulfilling NASA's overall mission.

Although NASA's planning process is a very valuable aid in program definition activities, and has evolved throughout the Agency's history, it still is by no means a perfect tool. We are continuing to improve it and extend its reach. Furthermore, it is a tool that can be complemented and enhanced. This Committee specifically, and the Congress more generally, plays a fundamental role in the process by overseeing, evaluating and, on occasion, modifying, NASA's planning. I commend the Committee for its interest in the long-range planning of the Agency. A particularly noteworthy instance in which NASA's planning effort has been substantially enhanced is the creation of the National Commission on Space, an initiative for which this Committee is responsible. The National Commission, in its report to the President and the Congress next year, will provide a comprehensive analysis of program and policy options which will inform NASA's planning for entering the next century.

Over the two days of briefings you will receive details about the future plans for each of NASA's major program offices. I have been asked before by Members of this Subcommittee about where I see NASA in 25 years. Let me take the opportunity to offer my ideas.

Within a decade, we'll be operating permanently in space. Our base will be the Space Station we are beginning to develop now with our friends in Canada, Europe and Japan. The Space Station and the new technologies and discoveries that will come with it will expand the peaceful uses of space and their applications to an extent we can hardly imagine today. This expansion will be far-reaching and will include a wide variety of scientific, commercial and technological endeavors. Most important, it will assure United States leadership in space through the end of this century and well into the next.

With such a permanent base in space, we will also be able to reach, retrieve, maintain and repair such important satellites as the Hubble Space Telescope, which is scheduled to be launched in 1986. The Space Telescope and other advanced observatories we plan to launch through the mid-1990's will revolutionize astronomy. They will expand our view of the universe to its very edge and allow us to see into the hidden depths of the entire electro-magnetic spectrum. By being able to repair these satellites and update their components in orbit we will be able to lengthen their life and scientific utility to about 10 to 20 years. This is ten times the one or two-year lifetime of most scientific satellites in orbit today.

The Space Station will also give us a permanent laboratory on orbit, where government and industry, working in partnership, will do the microgravity research, a necessary precursor to new products and new manufacturing technologies. Results of experiments aboard Spacelab and other Shuttle missions indicate promising opportunities for space processing of new medicines, new alloys, pure crystals and other products that will have widespread applications on earth.

The Space Station will also open the door for future, more ambitious missions. We expect that by the year 2000, the station and its associated platforms will be equipped with a supporting infrastructure that will enable us to operate routinely, both at low earth and geostationary orbits, as well as between them and, eventually, at distances as far as the moon and the inner planets.

Thus, the Space Station and its infrastructure will be the enabling technology to allow us to plan missions to open space to detailed exploration and human habitation, much as another enabling technology, the airplane, helped to tame the vast, uncharted regions of Antarctica.

We will continue to build upon our major successes in space science and in the applications of space technology. In astronomy and astrophysics, we will build upon our early achievements with OAO, the HEAO's, IRAS and the soon-to-fly Hubble Space Telescope. We will be able to enter the era of the great observatories wherein, we will have available research tools of unparalleled power for systematic scientific exploration of the sun, the more distant stars, and the enormously energetic sources such as quasars and pulsars that challenge our fundamental notions of the universe and its origins. The path to this future is being defined even now in the Hubble Telescope and Gamma Ray Observatory development efforts and in exciting new projects emerging from our planning such as the Advanced X-Ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF).

In the field of planetary exploration, we have a unique opportunity to continue our systematic exploration of the planets and primitive bodies in the vicinity of the Sun. Following the carefully constructed program strategy laid out by the Solar System Exploration Committee, the coming decades should provide us with our first close encounters with asteroids and comets and more intensive investigations of the inner and outer planets. Significant efforts have been made to provide a means for carrying out less costly planetary missions in the Planetary Observer program and the groundwork for a new generation of planetary spacecraft (the Mariner Mark II) is being laid out as the means for conducting the first rendezvous with a comet (CRAF) and for the first visit to a moon of another planet (the Saturn Orbiter/Titan Probe). Looking farther to the future, we will no doubt return to our nearest neighboring planet (Mars) with rovers, sample returns and in the longer range, perhaps a manned mission, to extend the human reach to another planet for the first time. Taking a twenty-five year perspective, much of the necessary technology should evolve to make such a venture feasible.

We will not ignore the exploration of our own planet with powerful new tools made possible in space. The ability to transport, assemble and maintain observational tools in orbit will enable whole new classes of instruments for atmospheric, geological, and other scientific observations. When coupled with the increasingly powerful computational tools and the emerging interdisciplinary research programs, we will be able to lay the groundwork for a truly unified "Earth Science" discipline of enormous practical value. The spadework for such developments is being carried out now in our cooperative efforts with other Federal and international agencies and with the worldwide scientific communities concerned with meteorology, oceanography and geodynamics. Ongoing and near-term projects such as the UARS will contribute significantly to our fundamental understanding of the atmosphere. Looking further to the future, the advanced Earth Observing System (EOS) to fly on the Polar Platform of the Space Station in the mid-1990's will provide major enhancements to our capabilities for remote-sensing of conditions on Earth.

As we look to the future we will have to think about ways to overcome size and weight constraints on what we can put into space. Sometime before the year 2000 we will probably need a new heavy lift unmanned launch capability to orbit objects that are larger and weigh more than we can orbit today. If we are to assemble large structures in low earth orbit and move them around with an Orbital Maneuvering Unit or use an Orbital Transfer Vehicle to lift them to geosynchronous orbit, we would no longer want to be limited by the present launch capabilities.

By the same token, we would probably want to construct a new generation of shuttles, smaller, lighter, more flexible and less expensive to operate than the present generation of multi-purpose vehicles. Their function, as part of a so-called "people-in-orbit" system, would be to ferry men and women and certain supplies to the Space Station and to assist in the "hands-on" work of retrieving, repairing and maintaining satellites.

Advanced technology provides the underpinning for these and other future space missions and is an essential ingredient to our continued preeminence in space. Enabling technologies for airbreathing-to-orbit transatmospheric vehicles and other low cost transportation systems; smart, telerobotic systems; and large power systems are but a few of the high pay-off areas we are pursuing in our Space Research and Technology program.

"Humanity is just a work in progress," wrote Tennessee Williams. Indeed we are. And as we evolve and grow, I believe we will demonstrate that there are no limits to our future in the universe.

That concludes my prepared remarks, I would be happy to answer any questions you my have.

Mr. NELSON. Thank you, Mr. Beggs.

A major part of your long-range planning is the merging of competing priorities which come to you sometimes in the form of recommendations from your associate administrators. And thus, your role is unique since the nature of these competing priorities are so different, such as shuttle development versus science as a competing priority.

My question is how do you separate the means, such as the shuttle, from the end, such as science?

Mr. BEGGS. Well, you really can't. The NASA program has over the last quarter century moved as a balanced program—we like to use that term "balance." By balance what we mean is that we try to assemble our priorities in such a way that the program develops new capabilities together; that is, as capabilities such as the shuttle come on line we have coming with it in the space science and applications area the experiments and the activities that we intend to pursue in science that complement or make use of the new capabilities of the shuttle.

We have been, I will admit, more or less successful in that. That is, in making sure that the use of our new tools is fully soaked up by new capabilities in science and applications. I think in general the program has been successful in making sure that it keeps priorities in space science high enough on the agenda that even when we get into trouble in some of our major development programs, like the shuttle, that we don't abandon or put large periods of schedule lapse into the Space Science Program.

I think in the past 5 or 6 years that the Space Science Program has done very well. It has grown substantially, and we've managed to bring into it a lot of new starts and new capabilities that fully utilize things like the shuttle. As space station comes into being, we are going to have to be careful that we do an equally good job in maintaining our thrust in the science and applications area so that the space station will be fully utilized in that regard.

It is, in short, a management job of a high order. We are, as you know, and I think properly so, ably assisted by the advisory committee structure and last, but certainly not least, the committees of the Congress which have oversight on the program in ordering those priorities.

Mr. NELSON. Do you have any thoughts about how you will use the advice coming from the National Commission on Space in your planning for the future?

Mr. BEGGS. Well, we've had several meetings with the Commission thus far, and we'll have a number of additional meetings while they work on their recommendations and their programs. I think that interchange will be of value to us in framing the options for the future. When the report is issued, if they do the job as well as I know they are capable of doing the job, we will have a road map, if you will, or a program that will extend out perhaps 50 years. And it should allow us, then, to use that as source material to plan programs in the next several decades.

I hope that that report will provide a time phasing of that sort. It's important, of course, that we keep in mind that in any decade or any period of time, the resources we have are limited and you've got to pick and choose in order to fit a program to limited resources. So you need to time phase any given program in such a way that you do the things that you can do well in the near term and then progress on to the things that are important for the future.

Mr. NELSON. There are so many players in formulating space policy. SIG-Space, the Cabinet Council on Commerce and Trade, DOT, DOC—all have their finger or are trying to get their finger in the pie. Now do you feel like that NASA has remained the lead civilian agency in space, and where do you see it going for the future?

Mr. BEGGS. Well, I think without question NASA still exercises a leadership role in the Civil Space Program, and I think—we still have a fairly major role even in the military side; that is, things that the military adopts for their own use tend to have at least some origin within the civil program. I happen to believe that eventually the technologies and the capability we develop in space station will be used to some extent by the Department of Defense.

Our ability to retain that leadership position I think depends pretty much on how well we do the job of both managing the current program, that is, the program we have on the table now for the next 10 years, and how well we plan and work ourselves into the future. Probably that encompasses more strategic planning, or more of a look at strategic planning than it does long-range planning. It's fairly easy to do long-range planning in this agency. You can move from one program to the next. Twenty years is a short time span in our program because the current program we have generally runs out over a decade or so, and so the 20 years is merely the program activities you'll be conducting beyond the one you have currently in development.

But the political environment, the economic environment, the environment that will exist on the commercial side; the aspects of what's going to happen in the rest of the world—and as we all know, the rest of the world is getting intensely interested in space right now—how fast they will come along, how much money they intend to spend; what will happen with respect to our adversaries, the Soviets, what has Dr. Sagdeev got up his sleeve for the future; all of those things I think will play into the potential of what we do and how we do it in the next 25 years. And when I say strategic planning, I'm talking about taking all of those factors into account.

Mr. NELSON. Now on the international scene, do you think you have sufficient control over the international cooperative activities vis-a-vis the State Department and anybody else that gets into the picture as you look to the future in defining your areas of cooperative ventures?

Mr. BEGGS. Oh, yes, Mr. Chairman, I think the Agency definitely takes the lead in those. In the period of time I've been here we've had no arguments or quarrels at all with the State Department as to how and when and why we do certain things. The initiatives we have been carried out I think in close concert and happy harmony. And generally they look to us to lead them down the line as to what has to be done technically. We rely on them to help us in making sure we take into account and are sensitive to those things on the foreign scene that will have effect and influence over what we do.

Mr. NELSON. So in the foreign area, perhaps the only one you don't have sufficient relationship that you would like is with someone like U.S. Information Agency, by virtue of the fact that little was told about the story about how a hundred million Arabs from Morocco to Indonesia were absolutely mesmerized in front of their TV screens on the 7-day mission of Prince Sultan of Saudi Arabia.

Mr. BEGGS. Well, I have to say the USIA sometimes takes liberty, but they have been very good. And I think rightfully so, they have been very good at making use of the shuttle flights to communicate in a proper way with the rest of the world. I think some of the broadcasts that they've put on during the flights have really been splendid. And as we get into the period when we will have a full TDRS system operating—the Tracking and Data Acquisition System operating, we will be able to broadcast live from the shuttle and watch what they're doing up there from time to time, which I'm sure doesn't fill the astronauts with any great degree of joy but should add to the spice of those broadcasts.

I think the USIA generally has done a very good job. Sometimes they take liberties with what we're doing up there in their broadcasts and television broadcasts around the world.

Generally speaking, I think the Space Program is an outstanding example of what this country can do in both showing the rest of the world the vitality of the American system and at the same time providing them access to major technological benefits. I think it's one of the best things that the United States does around the world in sharing with them both the excitement of the program, the spice and vitality of the program, and we truly do give it to them. The amount of money we charge generally is no more than the cost of what we provide them. This gives them access to technology that is truly well beyond anything they could get in any other way.

Mr. NELSON. Let me ask you about the budget. Your long-range plans demand a great deal of budget stability for the future. You want to state for the record what kind of real growth you think you need to maintain a robust space program?

Mr. BEGGS. Well, I've felt and expressed a number of times, Mr. Chairman, I think the program, if it is to maintain the thrust that it's had for the last several years, has got to be kept whole for inflation. That is, the budget has got to remain at levels equivalent to escalation. And the agreement that was struck at the time we got the space station approved, which was 1 percent real growth in the budget, would be enough to provide for some new starts in space science and some of the other areas and allow us to do a little modernization here and there which we have to do from time to time to keep the institution healthy.

I really think that in the long term the Nation ought to be investing more in research and development, research and technology, and this program, of course, represents probably the best example of what the Federal Government does in research and technology. In my eyes, the Federal Government should invest in research and technology in three, and perhaps four, areas. One is where the facilities and the program cost so much that our industry simply can't afford to put up the money (get that much capital to do it). Second, where the program payoff is so long range that you can't do an economic analysis and make the investment pay, but yet the R&D is so important that the Nation needs to do it. Third, where the industry is so fractionated that they can't get up a critical mass to do the R&D. And fourth, I guess you can throw in research dedicated to defense, which is important. Now the first two are the things that we do in the Space Program. The third is exemplified by agriculture.

But we are spending less today in real terms than we were 20 years ago. We were spending significantly more at both the Federal and the private level. It was 60-40, 60 percent Federal and 40 percent private, in our total investment in research and technology in 1965, but it was almost 3 percent of the GNP.

Mr. **Nelson**. Is that research and technology on everything, or just space?

Mr. **Beggs**. Everything.

Mr. **Nelson**. Everything.

Mr. **Beggs**. Everything.

At that time in 1965, I think NASA was spending something like 3 percent of the Federal budget, which would have been in the order of maybe seven-tenths or eight-tenths of 1 percent of the GNP. Today we spend eight-tenths of 1 percent of the Federal budget, which is two-tenths of 1 percent of the GNP on space.* I'm speaking from memory. These figures are all in the——

Mr. **Nelson**. Sure. So——

Mr. **Beggs** [continuing]. Statistical Series. But now we're spending 2.2 percent and that is a significant decline. It may explain why we've become less competitive in a number of major industries in this country.

Mr. **Nelson**. But your goal would be over the next, say, 3, 4 years to have 1 percent real growth each year?

Mr. **Beggs**. Yes, sir. And I would hope in the long run that the program would grow with the economy. I think R&D should grow with the economy; that is, it should remain a constant percentage of the GNP because it is the wellspring from which that new GNP comes.

Mr. **Nelson**. Indeed. Indeed. I hope that message is getting across.

Before I turn to Mr. Smith and Mr. Walker let me just ask you this. Do you think there is any merit to a multi-year authorization process?

Mr. **Beggs**. Very much so. I would dearly love to see you go at least to 2 and perhaps even 3 or 4 or 5 years on the program authorizations and appropriations. That would not remove, of course, your capability and authority to oversee any of those programs in the interim, but it would allow us to do our planning in a much more effective way.

Mr. **Nelson**. Mr. Smith.

Mr. **Smith**. I don't have any questions at this time, Mr. Chairman.

Mr. **Nelson**. Mr. Walker.

Mr. **Walker**. Thank you, Mr. Chairman.

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*See appendix, p. 221.

I was interested in your discussion here a couple of minutes ago about the percentages being devoted to R&D. Let's look at the microcosm, though, of space on that. If you take what private industry is investing in space today, put that together with NASA's investment, are we anywhere close to the levels that we were spending in the 1960's if you combine both of those?

Mr. **Beggs**. No, sir. Now, if you take the civil space, which is the one I cited, and combine it with the military space, you are somewhat closer to the levels we were spending back in the late 1960s, but we are still not up to them, as I read the figures.

Mr. **Walker**. Even with the massive investment going on in communication satellites, the whole communications industry? A million people working in that industry based upon communications satellites, are all of that activity within the GNP, that doesn't add into——

Mr. **Beggs**. I take great pride in the fact that I think the space program stimulated that revolution. It's estimated that the communications business associated with communications satellites is somewhere in the vicinity of anywhere from $4 to even as much as $10 billion worldwide. But you have to remember that of that a relatively small part of it is space technology per se; most of it is ground equipment. Now those are advances in communications to be sure, but they're not advances in space technology per se.

The satellite industry, the industry of this kind, we have most of it. We still have 90 percent of it in this country. The satellite industry in total in this country is a several hundred million dollar a year business, but no more than that.

Mr. **Walker**. Yes. I realize that you're making a distinction here between R&D activities and some other things.

Mr. **Beggs**. Yes, the R&D we found went on in communications satellites from the time we turned it loose with the Comsat bill. And if you recall, Mr. Walker, we ended the NASA R&D in communications for a period of time. We found that the amounts of money they were committing to R&D were very, very small, And so about 4 or 5 years after that revolution began we went back into it, and now we are again doing research and technology at the Federal level.

The point I'm making is this. I think you can count on the industry to do that research and technology where they can see the payoff in a discrete period of time where the economic payoff can be justified. Everybody can do a discounted cash flow analysis these days. And if you've got interest rates running even where they are now, 8 percent or 9 percent a year, that's a doubling every 6 years, and that means unless you can see it pay off in 6 years or so you really can't justify putting money into it. Because a businessman has got to get his money back. If he doesn't, he goes out of business.

So if you want to make up for the long-term research, there are only two places to get it. One is at the universities, which is to a large extent financed federally, although some private, and the other is in the great governmental laboratories like NASA.

Mr. **Walker**. Well, then I think it is necessary, though, to make a distinction between space as an R&D activity and space overall. What I was asking was whether or not space and space-based industry and space-based economics is not at least as big a share of the total GNP today as it was in the 1960's when obviously all space activity in the GNP was R&D?

Mr. **Beggs**. Yes, sir. I'm sorry. I think you're right. I would agree with that.

Mr. **Walker**. So then, in fact, while the R&D portion of it has changed, and that has largely been a case of the cutbacks in the amount of budget devoted to NASA-related activities—I would agree with you that industry has not done much R&D—the fact is that spawned off of that R&D you do have significant amounts of private enterprise which in fact the impact on the GNP is significantly larger than just the R&D portion.

Mr. **Beggs**. And all of that private industry is generating tax revenues.

Mr. **Walker**. Yes.

Mr. **Beggs**. Very nice.

Mr. **Walker**. The reason why I raised the question is because I think that it somewhat, though, begins to guide us in some of the thinking that we ought to be doing toward long-range planning for NASA in the future. Because I think that the question begins to arise, at least in my mind, as to how NASA approaches some of these things, to assure that adequate resources are there for R&D activities. I mean it goes back to the question we've discussed before and we don't have to go into any detail here of ultimately selling off the shuttle fleet. Because the more the shuttle fleet becomes an operational entity within NASA, the more that is a drain from R&D activities rather than a specific R&D activity. And yet, the appropriations flow through this subcommittee and, you know, the question we begin—at least I raise in my mind, is whether or not in that appropriation flow I want operational technology or whether I don't want that operational technology off somewhere else and be devoting that whole amount of money to strictly R&D.

The same thing occurs to me with regard to development of the space station. It is fine to see the space station as a total R&D tool. On the other hand, it may well be that the space station has a lot more merit as a tool other than just R&D. That there ought to be some other kinds of planning on it. And we've mentioned in the hearings here before about deciding what kind of power supply should be to the space station or questions of that kind.

I guess the question I have for you is whether or not in the long-range planning that you're doing are you looking at the potential for significant contracting out, for significant buying of services from private industry that is space based as a way of getting infrastructure in place that ultimately would support R&D activities but may not directly be fundable R&D activities through NASA?

Mr. **Beggs**. Yes, sir, we are.

Mr. **Walker**. And in what ways? Where?

Mr. **Beggs**. We've taken several looks at the business of turning shuttle as an entity over to a private or a quasi-private, quasi-Government organization, and we're continuing to look at that in our long-range planning. As a matter of fact, it's high on the agenda.

We have over the last 10 years tried to move those things which are routine out of the Agency into contractor organizations. The purpose of that is to keep the NASA organization focused on the research and technology to keep the scientist and engineer population of NASA as high as we can so as to maximize the scientific return. Now, if we can find a way to transfer those operational responsibilities fully to a private enterprise where they could operate for profit, we're going to do it We haven't quite found a way to do that in the case of the shuttle, nor have we found a way to do that in some of the other aspects. But we have transferred significant pieces and parts to contractor organizations.

Mr. **Walker**. Well, how much—is that being looked at with regard to the next big project, space station? One of the concerns that I have is that as I see the designs emerging from all the various people who are doing the work, they all seem to have the same reference design. I mean, in terms of being somebody with a nontechnological background, virtually everybody who shows me their design for space station it looks exactly the same, which tells me that they have pretty much decided on power tower, they have decided on a few things as being the essential——

Mr. **Beggs**. I hope it doesn't turn out that way. But we gave them a reference configuration and that's where they're starting. You may want to ask that question again to Mr. Culbertson. But my hope is that those studies will expand and perhaps move from that reference configuration into something better, if it turns out that there is something better.

Mr. **Walker**. Well, that's my question. Because the one thing that's been mentioned to me that might be better, and I'm just wondering how much exploration is going on into that area, is as we move toward a time when we're going to begin to think about finalizing these designs, and one thing that's been mentioned to me is buying power from a private source in space. Rather than having the whole design centered around the supplying of power to the space station, actually buying power from somebody who flies strictly a power station in orbit. And I don't see anything in any of the reference designs, any of the talk that I have heard, that anybody is really looking at that as a real possibility as we proceed down the line of spending money for the design.

Mr. **Beggs**. No. Our concept encompasses private participation in the station.

Mr. **Walker**. I understand. But that's a little different concept than, for instance, having a station which you build that essentially has only an emergency power supply aboard it and you're buying power from somebody who is supplying you with the power from another station which then would also have the ability to supply power to the industrial park that you've already contracted for, with the Faget concept that would allow the shuttle to stay on station for much longer times because the shuttle could then purchase power for long duration flights from a similar kind of station.

In other words, I don't know whether that works or not. Again, I'm not someone who knows the technical, but——

Mr. **Beggs**. I don't, either.

Mr. **Walker** [continuing]. There are technical people who say that it works and that is really emplacing, then, infrastructure that supports R&D rather than NASA doing the total work of building that infrastructure. And I'm curious as to how much thinking in the long-range planning of NASA is going into that kind of reference rather than references that are strictly NASA designs.

Mr. **Beggs**. Well, if we aren't thinking of it now, we will.

Mr. **Walker**. OK. Thank you.

Mr. **Nelson**. Mr. Beggs, I know you have the time constraint, and I will follow up with your associate administrators on a number of items that you have stimulated our thinking on, such as the heavy-lift, unmanned vehicle, things like new generations of shuttles. You talked about transatmospheric vehicles.

Another thing that is in the news, of course, is that with the satellite failures—again underscore—having nothing to do with the extraordinary success of the space transportation system, we have had satellite insurance claims of $570 million in the past 18 months. Now, we are going to have a hearing just on that subject I think on October 30, but we might want to broach that as we're looking at our long-range plans today. So perhaps I can talk to you about that, Mr. Moore.

Mr. **Beggs**. Yes, sir.

Mr. **Nelson**. All right. Thank you, Mr. Beggs.

Mr. **Beggs**. Thank you, sir.

Mr. **Nelson**. Hope you make your next appointment.

Mr. **Beggs**. Thank you.

Mr. **Nelson**. All right. Mr. Culbertson.

STATEMENT OF PHILIP E. CULBERTSON, ASSOCIATE ADMINISTRATOR FOR OFFICE OF SPACE STATION, NASA, WASHINGTON, DC

Mr. **Culbertson**. Thank you, Mr. Chairman.

It's a pleasure to be with you today and discuss the long-range planning which is associated with the space station. The space station is rather unique—at least in my belief it's unique—in the kinds of programs that NASA is planning and its relationship to long-range planning. And that is, if it is to be successful, to remain in orbit for a period of 20 or 30 years, it must plan to evolve. And that's my definition for long-range planning. It's a definition that we have used for a long, long time. Yet, we must be able to change its capabilities, to add to its capabilities, and to augment the existing capabilities when there is a demand for them.

So if I can—I'm going to just use a series of slides and talk about them without having submitted to you a prepared statement.

The lights are going to have to come down a little bit somewhere.

The first chart (fig. 1), when it is visible, will remind you of what the reference configuration for the manned part of the Space Station Program is.

And, Mr. Walker, let me comment on your remark that it seems like all the contractors are using the same design. When we wrote the RFP—the request for proposal—we felt it was necessary to illustrate the kind of thing that we were talking about and use it as a reference configuration, so that all the contractors would have an equal opportunity to understand that portion of the program on which they were about to bid.

And this was the power tower that you referred to. It is the common illustration of the manned part of the space station. And it is this configuration which we have been for the last 4 months and will continue for the next 5 months to tear apart bit by bit and examine it, with our contractors, one piece at a time, and then put it back together about the end of this calendar year into what we will then call the reference configuration in which we will proceed, the rather detailed design.

Now, the process that we're going through, and it was not part of my plan to talk about this at this hearing, but let me describe the process a little bit. We have about 70 characteristics of this space station which we are asking our contractors to examine and to assist us in determining the proper changes to incorporate into the final design. And I won't talk about a lot of those, but let me illustrate it.

On this configuration you can see that we have a particular arrangement of modules, and a location of those modules on the space station. And we're asking the contractors to help us determine what the right size of those modules should be. Other than just the illustration you see here specifically what the proper length of them should be; what the internal pressure of the system should be; how they should be joined together; and in what kind of an arrangement. One that the entire configuration should be accessible to the crew and, even more importantly, where on the overall vertical arrangement, if there is a vertical arrangement—diagonally to the upper right—where those modules should be.

Where they are located now there is an inherent gravity during the orbital flight of about 5 times 10 to the minus—10 times 10 to the minus 5—10 to the minus 5 g's. That is, it's about .001 of the influence of gravity. That is a little bit more than some of our users would like to have in a space station, and the way to reduce that is to move those modules, the pressurized modules laboratories up some; up more toward the middle of the configuration. So we are examining many different aspects of the pressurized modules to determine where is the right place.

We are examining the overall structure for tying the modules into the solar arrays and will undoubtedly make some changes in what you see there. We even examined the possibility of flying this oriented 90 degrees from the orientation that it has today.

We are looking to see whether we should locate provisions on the outer ends of the booms on which the solar arrays are located in order to put instruments that might point to the Sun. Because those solar arrays will be located so that they will constantly point to the Sun. And comparing that location with the location at the top of the overall configuration.

As I say, there are about 70 of these basic decisions which we are in the process of making in a fairly systematic way, one-by-one, during this fall and winter season. However, we need to have a continuous reference to be comparing those studies against, and we need to have a continuity in the program to tie all of the eight contractors together. At each one of these decisions, all the contractors will be doing their own work on alternatives and the merits and relative costs of those alternative configurations and decisions.

Rather than try to show illustrations of each progressive change, we'll wait until toward the end of the year and wrap all those up into a single change. You will see very fundamental changes in that time period to which all of the contractors have been a party.

The part of it that you see here with the shuttle dock and the way with this configuration the shuttle would deliver materials and crew to the space station is the manned part of the system.

The next chart (fig. 2) illustrates what we call a platform, and that was done on a computer. We believe that the Space Station Program should accommodate both instruments and processes which need to use man and those which cannot tolerate the presence of man, and so we have included in the program a couple of platforms which will fly those kinds of things that do not care for the natural disturbances that man provides as he walks around the space station or pushes off the walls of the space station or the contamination effects of having an environmental system in the spacecraft. We will either plan to fly the platforms in Sun-synchronous orbits, which are of value to some people, or in a co-orbit with the basic manned part of the space station.

The point of including this is to say that there really are a number of pieces, at least two or three spacecraft involved, one which will be fundamentally manned and one, two, or three that are unmanned, and we are still in the process of making our choices on those.

The next chart (fig. 3) illustrates how these tie together more or less in an overall infrastructure, or architecture. The manned system is illustrated by those various capabilities in that inner set of circles with the shuttle flying to it. The unmanned platforms are over to the right. The kinds of users for the unmanned platforms are some of the astronomical instruments, and Earth observations from Sun-synchronous orbits. Where gravity is particularly acute factor in the research, flying on the unmanned system will provide the lowest possible gravity, and there are a number of other possibilities for users in the unmanned platform.

While I am there, incidentally, let me say that in my total view of the space infrastructure I think that the work that is being proposed by Dr. Faget and Space Industries, Inc., in Texas, falls to that right-hand side in a lot of respects. It is a man-tended concept that he has, but I believe that it contributes in a very complementary way to the other things that the space station will consist of.

Growth elements, those things beyond that which we believe are appropriate to incorporate in the initial configuration, include more laboratories or habitats, which imply greater opportunities for research in science and other disciplines and the larger crews, more power, the provisions for docking the orbit transfer vehicle—the OTV—to the space station for that time when that vehicle is appropriate for geosynchronous operations or deeper space missions.

There are other kinds of growth elements that I'll mention later on, but they're related primarily to the base although they involve the platforms, too.

The next chart, please (fig. 4).

Let me remind you that the space station is a fairly versatile kind of a machine, and the things that I list there are those which we have discussed since we originally began the program. All of those things are being examined as we develop what we call the Initial Orbiting Capability [IOC] configuration to determine how much of each one of those we can logically incorporate into the original space station; how much will have to be deferred; or, how much will have to be accommodated some other way because there may be some basic incompatibilities with some of the other things.

Mr. Chairman, you spoke of long-range planning as being one of merging priorities. And as you said merging, I think of merging into the beltway sometimes; and user priorities or options for using the space station sometimes at the same time. There is not always total harmony among those people who would be our users, and our question is how much of this we can logically and effectively incorporate into the space station. I won't belabor these things but they have been part of the program since we began it, and we are continuing to examine the extent to which it can serve each of these functions.

The next chart (fig. 5) lists a few of the parameters which are inherent to our overall concept. We are linked to the space shuttle as our transportation system. We are now working MOU's—Memoranda of Understanding—with Canada, the European Space Agency [ESA], and Japan, for their participation with us as we do the program definition effort. All of the potential users which we are working with are involved not only in helping us to define the basic system, but then to contribute to an understanding of the requirements in the detailed design.

We are following Congress' direction in using the space station and in planning to use the space station as a target of focus for automation and robotics [A&R]. The Department of Defense is not a participant today, but, as Mr. Beggs said earlier, they are certainly a potential user ultimately.

Space station will be a permanent facility, as permanent as we know how to build it and that means 25 to 35 years, in that order of magnitude; and our intent is to have this operational within the decade that the President asked for.

Our schedule for planning is shown on the next chart (fig. 6), and I give you a possible evolutionary scenario. It's a little hard before the program has even begun development to be precise about the next increment of capability, but on the top you can see the initial capability leads to launch and assembly and the verification of operations in the early nineties. We are today doing the necessary thinking about evolutionary direction so that we can incorporate into the basic system, the opportunity to evolve when that time comes. I look toward the late 1990's as the time when it might be considered appropriate to say we will by that time be adding capability.

I'll talk a little more about schedule later on. It's very possible, for instance, that the first thing which we will add is the provisions to fuel and launch the orbit transfer vehicle and then have it come back to the space station and be prepared for a subsequent launch.

Our basic approach to long-range planning is shown on the next chart (fig. 7), and we start first by saying because it is different there are some differences to the way we will plan it. It is not only permanent, but it is permanently manned, and it must therefore be evolutionary. It is not possible for us to predict today the precise use or requirements for the space station in the year 2010, but we know that it must evolve when we find out what that requirement is in 2010.

We are involving our international partners—and I mentioned them before—in our thinking about evolution. We're involving the users in our thinking about evolution, and a number of advisory groups: the National Academies of Science and Engineering and the normal NASA structures for advisers, and many other people who are glad to add their advice to the way we ought to go in the program.

We are developing an operations concept which is consistent with long-range planning, and I have instructed the people who are working on that plan to make sure that as we develop it, we develop it in a way that it can be transferred out of NASA; the operations system can be transferred out of NASA if we find that it should be done. We are not trying to force a decision today on whether it should be done, but we must develop it, I believe, in a way, and plan the operations in a way that facilitates its transfer away from NASA if that turns out to be a desirable thing to do.

We are conducting technology development activity which supports not only the basic station, but make sure that as we decide that there should be evolutionary growth or changes to it, the technology will be ready.

And finally, we are working in our thinking to accommodate the commercial user and people like Dr. Faget and his spacecraft to work with us so that as we evolve, he too—they too, will be able to evolve in their work with us.

The next chart (fig. 8) is just a set of principles. The phased evolution of the space station is just an assumption. We assume and are proceeding on that direction. The direction today requires the identification of proper scars on the space station so that we can evolve, and the planning for the timing on that evolution is open as we examine the needs of the using community. I mentioned that the OTV was probably the first element of evolution, and I believe that it will come before the year 2000.

Our experience with the early station operations will, I think, give us an indication and help us in our plan for evolution.

I am going to pause a moment while I wait for the present technology.

OK, let me have the next chart now, if you would (fig. 9).

As we look at that evolution today, it's clear that it is—well, I shouldn't say it's clear. It's highly probable that power, crew size, and pressurized volume will be the first things that we find must be expanded. Our assumption is that each one of these basic assets that the space station provides will be added to as time goes by.

Expanded servicing is also high on our list because we intend, with the space station, to provide services to free-flying spacecraft such as the space telescope and other laboratories that are developed over the next few years. There are also new functional capabilities that we expect to add: greater provisions for the building of large structures, or the assembly of large structures, and I mentioned transportation.

We also believe that it must be able to evolve in another direction, and that is to take advantage of new technologies, whether they are automation and robotics or other kinds of technologies, which will enhance its performance or reduce its cost.

The next chart (fig. 10) indicates that we are looking at several evolutionary scenarios as we determine how to accommodate the opportunity for growth. One, for instance, would be that commercial manufacturing could by the turn of the century have a quite different complexion or demand on the system than we have today, and we will want to accommodate it. The possibility of large platforms in geosynchronous orbit and manned operations in geosynchronous orbit would use the space station as the jumping off point. Clearly, the work of the National Commission with respect to considerations on the lunar base and the planetary exploration will be taken into consideration.

There is another scenario which would say we would expand and make greater use of low Earth orbit in research or operations. And there are others.

We are examining each of these to see what their implications on the space station might be with respect to technical considerations, budget and schedule, and then we will determine how to accommodate the greatest range of possibilities in evolution that we can on the present configuration. We will do that because we are certain that by the time we must make the decisions on the present configuration, we will not know what those evolutionary paths might be.

Next chart, please (fig. 11).

The challenges that we face as we do this long-range planning is that we are first trying to key all of these ideas from the users, and they are the multiple users whose requirements will steer the growth directions which we must take. Now those users are not yet fully defined and they have not defined what their requirements will be, and we know they will change over time and that they will sometimes conflict with each other. It is our responsibility, I believe, then to pull those together and develop a single opportunity within the present program to evolve.

Mr. NELSON. Mr. Culbertson, I want to interrupt you here because we're going to have to get moving on. How about just starting to wrap up into a summary the remainder of your comments?

Mr. CULBERTSON. Right.

Mr. NELSON. And then we're going to do something different here. We're going to, rather than question you we're going to get a participation of the entire panel going here.

Mr. CULBERTSON. OK. Let me go to the last chart (fig. 12), which is a set of conclusions, and show that. If you have it, it says "Conclusions."

I believe that the successful strategic planning or the successful long-range planning does require a well-understood vision of what must be accomplished and a recognition that the space station will be permanently manned; that it will be designed to be, as we say, "User Friendly;" that it is international in scope; that it must be affordable and within the budget; and it must be developed within a decade. We've got to understand what our costs are going to be and then we must put cost controls over those not only with respect to development, but lifetime operations.

The planning for evolution requires identifying the directions, and we are working with that and anxiously, as I said, looking for the Commission's observations on it. Then properly scarring the initial space station so that we can accommodate that kind of growth. Then finally the realization that choices will have to be made because we can neither scar to do all things nor will we be able to scar some of the things that we feel are appropriate. There are going to have to be other choices made as weil.

Thank you.

Mr. NELSON. All right. Thank you.

[The charts referred to follow:]

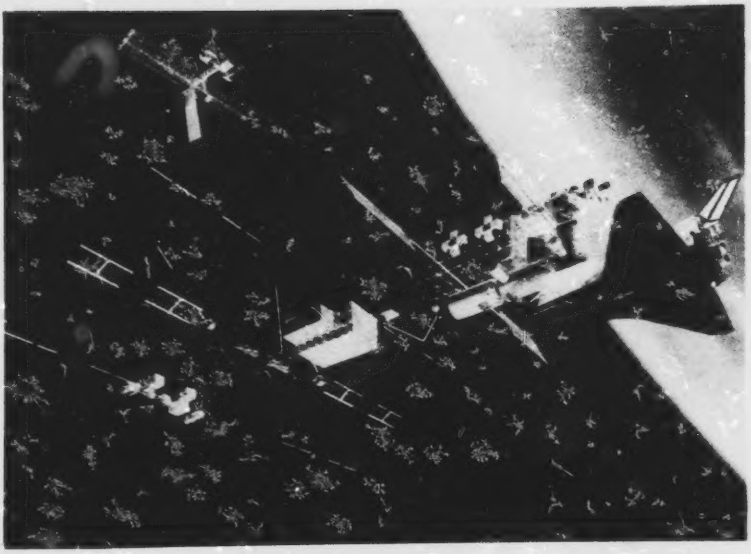
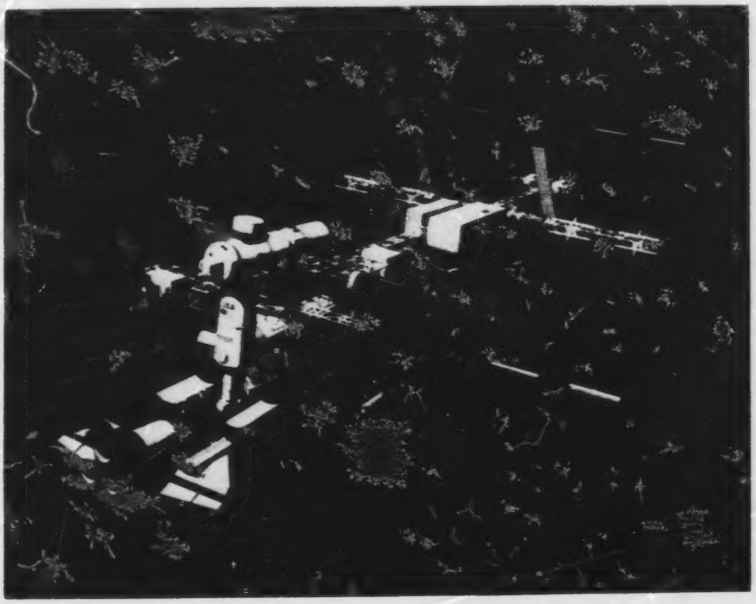
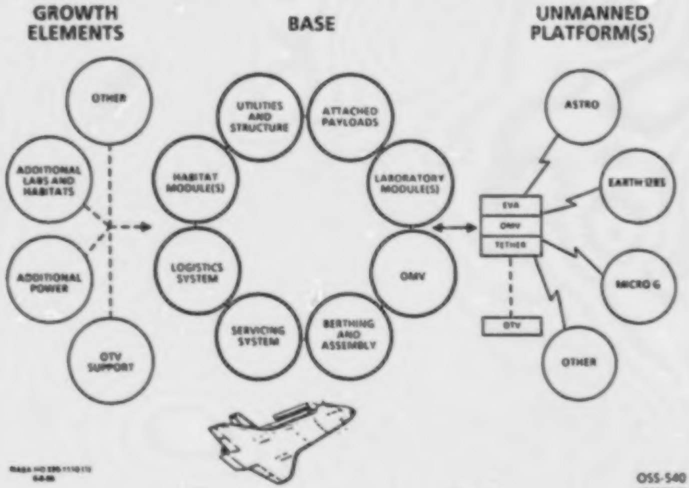


FIG. 1



SPACE STATION PROGRAM ARCHITECTURE


GROWTH ELEMENTS
BASE
UNMANNED PLATFORM(S)
OTHER
ADDITIONAL LABS AND HABITATS
ADDITIONAL POWER
OTV SUPPORT
UTILITIES AND STRUCTURE
ATTACHED PAYLOADS
HABITAT MODULE(S)
LABORATORY MODULE(S)
LOGISTICS SYSTEM
OMV
SERVICING SYSTEM
BERTHING AND ASSEMBLY
EVA
OMV
TETHER
OTV
ASTRO
EARTH OBS
MICRO G
OTHER

OSS-540
(OSSTT-2)

FIG. 3

SPACE STATION

- a national laboratory in space
- a permanent observatory
- a servicing facility
- a transportation node
- an assembly facility
- a manufacturing facility
- a storage depot
- a staging base

A space station is a multi-purpose facility

FIG. 4

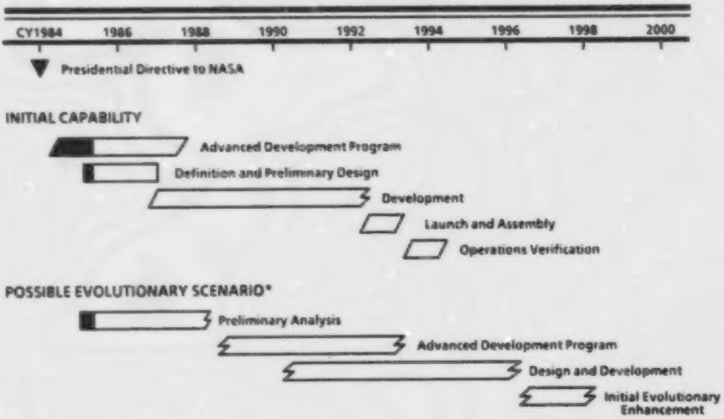
SPACE STATION BASELINE PARAMETERS

- SPACE SHUTTLE WILL BE PRIMARY TRANSPORTATION SYSTEM
- CANADA, EUROPEAN SPACE AGENCY, AND JAPAN PARTICIPATE IN SPACE STATION PROGRAM AS GENUINE PARTNERS
- SPACE STATION USERS ARE INVOLVED IN DEFINITION AND DESIGN
- CONGRESS IS ENCOURAGING ENHANCEMENTS IN AUTOMATION AND ROBOTICS
- DEPARTMENT OF DEFENSE IS NOT A PARTICIPANT IN THE SPACE STATION PROGRAM BUT IS A POTENTIAL USER
- SPACE STATION WILL BE A "PERMANENT" FACILITY
- PRESIDENT DIRECTED NASA TO DEVELOP THE SPACE STATION "WITHIN A DECADE"

OSS-875

FIG. 5

LONG RANGE PLANNING-SCHEDULE



*Illustrative only

OSS-897

FIG. 6

LONG RANGE PLANNING APPROACH

- RECOGNIZE SPACE STATION IS DIFFERENT
  - Permanent
  - Permanently manned
  - Evolutionary
- INVOLVE NON-NASA GROUPS IN PLANNING
  - International partners
  - Users
  - Advisory groups
- DEVELOP AN OPERATIONS CONCEPT NOW WHICH IS COMPATIBLE WITH LONG RANGE PLANNING
- CONDUCT TECHNOLOGY DEVELOPMENT ACTIVITY WHICH SUPPORTS EVOLVING USE AND REQUIREMENTS OF THE STATION
- ENCOURAGE AND ACCOMMODATE COMMERCIAL UTILIZATION

OSS-876

FIG. 7

LONG RANGE PLANNING EVOLUTION

- PHASED EVOLUTION OF SPACE STATION IS KEY PROGRAM ASSUMPTION
- DIRECTION OF FUTURE SPACE STATION EVOLUTION MUST BE UNDERSTOOD EARLY TO ENSURE PROPER "SCARRING" OF INITIAL CONFIGURATION
- DEFINITION AND DEVELOPMENT OF THE FIRST INCREMENT OF EVOLUTION MAY BEGIN BEFORE INITIAL ORBITING CAPABILITY (IOC)
- EXPERIENCE WITH EARLY SPACE STATION OPERATIONS WILL ENABLE US TO BETTER UNDERSTAND AND PLAN FOR EVOLUTION

OSS-877

FIG. 8

LONG RANGE PLANNING DIMENSIONS OF EVOLUTION

- ADDITIONAL CAPACITY
  - Power
  - Crew
  - Pressurized volume
  - Expanded servicing
- ADDITIONAL FUNCTIONAL CAPABILITIES
  - Large space structures assembly
  - Transportation - Orbit Transfer Vehicle (OTV)
- IMPROVED PERFORMANCE/PRODUCTIVITY
  - New technologies
  - Automation and robotics

OSS-878

FIG. 9

LONG RANGE PLANNING APPROACH TO EVOLUTION

- DEVELOP ALTERNATIVE EVOLUTIONARY SCENARIOS:
  - Commercial manufacturing and GEO platforms
  - Lunar base/planetary exploration
  - Expanded research and operations
  - Other
- UNDERSTAND CHARACTERISTICS OF EACH SCENARIO
  - Technical
  - Budgetary
  - Schedule
- SELECT AND ACCOMMODATE EVOLUTIONARY PATH(S) TO BE SUPPORTED

OSS-879

FIG. 10

LONG RANGE PLANNING: SELECTED CHALLENGES

- USERS: ACCOMMODATE MULTIPLE USERS WHOSE REQUIREMENTS
  - Are not yet fully defined
  - Will change over time
  - Sometimes conflict with each other
  - Exceed Space Station initial capabilities
- TECHNOLOGY: PROVIDE DESIGN THAT ENABLES TECHNOLOGICAL UPGRADE, ONE THAT IS INVISIBLE TO USER
- ENGINEERING: DEVELOP AN INTEGRATED SYSTEM THAT IS
  - Capable of long life
  - Maintainable on orbit
  - Evolutionary in character
- MANAGEMENT: ORCHESTRATE NASA CENTERS, INDUSTRY TEAMS AND INTERNATIONAL PARTNERS, RETAINING EFFORT IN EVOLUTIONARY SYSTEMS WHILE INTEREST INCREASINGLY FOCUSES ON INITIAL CAPABILITY

OSS-880

FIG. 11

CONCLUSIONS

- SUCCESSFUL STRATEGIC PLANNING REQUIRES A WELL UNDERSTOOD VISION OF WHAT IS TO BE ACCOMPLISHED. THE SPACE STATION WILL BE
  - Permanently manned
  - User friendly
  - Evolutionary in character
  - International in scope
  - Affordable and within budget
  - Developed "within a decade"
- COSTS MUST BE UNDERSTOOD. COST CONTROLS MUST INCLUDE LIFETIME OPERATIONS
- KEY TO SPACE STATION LONG RANGE PLANNING IS UNDERSTANDING THE POTENTIAL FOR AN EVOLUTIONARY CAPABILITY
- PLANNING FOR EVOLUTION REQUIRES
  - Identifying directions
  - Properly scarring the initial Space Station
  - Realizing that choices will have to be made

OSS-886

FIG. 12

Mr. **Nelson**. Mr. Moore.

Can someone hit the lights, please.

I would prefer instead of you going through each graph if you could just hit the high points——

Mr. **Moore**. Fine.

Mr. **Nelson** [continuing]. More in a conversational kind of way, and——

STATEMENT OF JESSE MOORE, ASSOCIATE ADMINISTRATOR FOR OFFICE OF SPACE FLIGHT, NASA, WASHINGTON, DC

Mr. **Moore**. Yes. Mr. Chairman, I won't go through every point on the Vu-Graphs, I'll go quickly through my set of charts here to give you some flavor of what we are talking about in our program in the Office of Space Flight.

[Figure 1.]

I'm delighted to be here this afternoon to give you a look at what we're looking at in the Office of Space Flight as far as future transportation systems are concerned. In order to set the framework for our planning, we obviously base that on a number of objectives or goals of our program. Right now, we are mainly focused on getting the shuttle in a fully operational status, make it cost effective as well as completing its development and exploring its capabilities.

We're also very actively engaged in looking at the next generation space transportation system, and I'll give you some detailed insight into what our objectives are in that arena very shortly.

Next, please.

[Figure 2.]

You're aware of the program status of the shuttle. We're now getting a number of our capabilities in place which has given us I think enormous flexibility in the Space Shuttle Program. We just completed our 20th mission. We now have our four orbiters. We are getting our second pad available at the Cape, and we are planning to initiate west coast launch capability in March of next year.

The shuttle, along with the many capabilities that we've demonstrated to date, is very unique and it is demonstrating a number of fundamental orbital capabilities which I think this country will capitalize on in the future, and will play a very vital role as far as space station and other program planning in the future. This chart tries to illustrate what we've done to date as a function of time. So let's go on.

[Figure 3.]

I think as a base for talking about next generation transportation systems it's important to think about the outlook for the STS; where do we think the STS is going to go over the next 5, 10 or 15 years. Our objective is to bring the STS to a full operational status, to continue to lower the operational costs just as low as we possibly can, get up to our advertised capability of 24 flights a year, focus on interacting and providing needed services to our customers, and to achieve a very flexible manifesting capability to change out cargoes very rapidly in the program; I think we will see in the Space Shuttle Program over the next several years some upgrades and increases in the system performance, such as upgraded avionics, maybe some more lift capability, and things of this nature, as what we advertise the shuttle is going to be looking like as a function of the next 5 years.

This sets a base for us, then, in terms of where we are going in the future.

[Figure 4.]

We define in our program four major long-range planning thrusts. These are:

[Figure 5.]

Orbital services, the second generation transportation system, what vehicle or vehicles will follow the space shuttle as this Nation augments its transportation system, what infrastructure do we need in place in order to meet the requirements of the users over the next decade or so in space, and then where is the country going on its next long-range program commitment. Do we go back to the Moon, or do we go to Mars? These are the kind of thrusts we're looking at.

Let's go to orbital services. This will give you a framework of the kind of things we see happening in our orbital services area from what's going on now in the repair/retrieval of satellites to where we think we're going to be able to get by the 1990, 1995, year 2000 timeframe. This chart I think will give you a road map to that, and I won't sit here and belabor that. But we're looking at capabilities that will refuel satellites, change out replacement units on orbit as opposed to bringing them back down to Earth for servicing. And I think this will be of fundamental importance to not only the services that the shuttle can provide, but I also think when the space station comes on line it will be of fundamental importance.

Mr. NELSON. By the way, what is the latest on the Leasat that you all repaired so successfully?

Mr. MOORE. Mr. Chairman, Leasat, or Syncom 3, as we launched back in April, was repaired successfuly. It is functioning well as of the latest word I've had on it. It continues to show excellent health signs. And it's my understanding that the kick motor will not be fired until probably around the latter part of October. The health of the satellite is looking very good as of this point in time.

We are delighted with the result, by the way.

[Figure 6.]

One of the fundamental elements of our orbital services which we've talked to the Congress about, and your committee, is the Orbital Maneuvering Vehicle [OMV]. This we think will provide a number of steps of capabilities to our space program in the late 1989, 1990s kind of time frame. You can see demonstrated on this particular chart a number of the kind of capabilities that it offers. We think it'll be useful as far as reboosting satellites, bringing satellites into the shuttle, as well as assisting in the Space Station Program during their buildup.

The OMV right now is in its phase B. In fact, we have just about completed phase B. We have three contractors studying the OMV: LTV, Martin-Marietta, and TRW. It will essentially extend the arm, or the capability of the shuttle by about 1,500 nautical miles as well as extend the plane change capability of the shuttle by about plus or minus 8 degrees. So it will give us an envelope of capability that I think will be very, very useful and very much needed in the overall space program that we're working on in NASA.

[Figure 7.]

Next in the major thrust in my program is what I call second generation space transportation systems. We've had over the past several years a number of studies underway looking at what the next vehicle should look like beyond the shuttle. These have now been focused into a directive that we are now working jointly with the DOD which has four major tasks to it. The framework for this study is defined up here where we were chartered by the President to do a 1-year study with the Department of Defense to go out and identify for this Nation what the next generation transportation system should look like.

We are well underway on that. We started that back in the mid-May timeframe, and we have put in place an organization with the Department of Defense that's shown in this particular chart.

[Figure 8.]

The study is codirected by NASA and the DOD. Our codirector is Paul Holloway of Langley, and the DOD codirector is Colonel Zersen of the Air Force. Mr. Aldridge of the Air Force and myself chair a steering committee made up of senior management members from each agency and we regularly review the progress in the study.

We have the major tasks of this study indicated in the boxes below on the organizational chart. I have to apologize; it's probably not visible on the screen, but essentially what we're looking at in this study is defining the mission model over the next 15 to 25 years, both civilian and military. We're also looking at the architectures or the system tradeoffs required to allow this country to choose a path for a launch vehicle system to meet the needs as defined by the users.

We are also identifying and developing program plans for the technology, the enabling technology that's critical to allow this Nation to choose a path for its next launch vehicle system. I'm pleased to say we now have our major study contractors under contract. We have four system contractors; NASA is managing two and the Air Force is managing the other two. We are very well coordinated in that study and, as I said, I think this is going to give us an insight, a wealth of information in terms of what our options are in this country as far as next generation transportation.

Mr. VOLKMER. Mr. Chairman, may I interject just on that point, as long as you're right there, because I may not be able to stay much longer?

Mr. NELSON. Yes, sir.

Mr. VOLKMER. Approximately what is the total amount that is now being used? How does—the total budget on this for the contractors in dollars or percentage?

Mr. MOORE. Yes, Mr. Walker; we have $24 million—Mr. Volkmer. I'm sorry.

Mr. VOLKMER. That's all right. Go ahead.

Mr. MOORE. We have $24 million between NASA and the Air Force on these four contractors. So NASA is contributing one-third of $8—we're contributing $8 million, Strategic Defense Initiative is contributing $8 million, and the Air Force is contributing $8 million. There's a total of $24 million involved in these four contractors which will run for a period of 26 months.

Mr. VOLKMER. I see. Thank you.

Mr. MOORE. OK. Let me continue.

[Figure 9.]

I know you can't read this chart on the screen, but you can look at this in your brochure. This just says the space shuttle, the space station, OMV, platforms all make up what we call the space infrastructure, and in order to fully utilize the space capabilities, or the space potential many of these elements will have to be developed and operated in the future, and they are things that we are considering very strongly in our long-range plans.

[Figure 10.]

Part of that infrastructure, a very critical part of it—I think Mr. Culbertson alluded to it earlier—is shown on this chart, which is what we call an Orbit Transfer Vehicle. This is different than the Orbit Maneuvering Vehicle in that this has a capability to reach geosynchronous orbit which the OMV does not.

We have a technology plan underway now between my office and Dr. Colladay's office to do an aerobrake flight experiment over the next couple of years which will give us a demonstration of this needed aerobraking technology. We think this will be fundamental to allowing us to achieve, at very high efficiencies, capabilities to go to geosync, service at geosync, potentially transfer men to geosync, and return back at minimum cost. We are very hopeful that we can bring this technology along so that it can allow us to enable an orbit transfer capability between low Earth orbit and geostationary orbit in the next several years. By several, I mean 3 to 5 or so years.

[Figure 11.]

This chart shows an evolution of our thinking to date on the Orbit Transfer Vehicle, showing us going into mid-1995 to the year 2000 looking at ground-based orbit transfer capabilities, then expanding that beyond the ground-based capability to a space-based system; and then looking at maybe manned OTV's as well as possibly looking at staging these systems to potentially achieve a lunar capability in the longer term.

So this is where our thinking is going relative to this particular piece of technology.

[Figure 12.]

In the final area of our program, Mr. Chairman, in terms of long-range missions we have had fairly low level studies underway for a number of years looking at potentially returning to the Moon, with a more permanent base on the Moon. We're also looking at operations in geostationary orbit; potentially a manned GEO platform or geostationary operations using man. And we also have had some studies underway looking at potentially sending men to Mars.

As you know, that's a long-trip time. There's a lot of fundamental things that have to be overcome for the Nation to embark upon a program like that, but these are some of the studies to try to identify the areas we ought to be focusing on if this Nation decides that's where it wants to go in the future.

[Figure 13.]

Some of the technology needs associated with these four major thrusts are shown on this chart. I really won't take the time to go through these in detail. I think you can read them. But in transportation, propulsion technology is really critical. In orbital servicing we need to look at automation/proximity operations. In spacecraft systems we're looking at specialized materials. We're looking at, again, automation/artificial intelligence. In life support/crew systems we're looking at the kind of things that will enable us to take men on long duration spaceflight.

[Figure 14.]

Finally, I've called out a number of issues here, long-range planning issues. Maybe the word issues is not the right word. It's something that ought to trigger our thought process in that all of us need to think about lowering the cost of operations in space. I think this is a fundamental thing we in the Shuttle Program are trying to achieve, and I think as more programs come on line with long attendant operational profiles we need to focus very much now on lowering those operational costs in the future.

We intend to continue to focus on fully exploiting satellite servicing. I think this is a very strong potential capability that we have demonstrated to date, I think, and pays some significant dividends. And I think for this country in the long term it can be an area that I think we can reap great benefits from.

The question we're looking at is the orbit transfer vehicle. I talked about the importance of that. We're trying to look at when is it really needed, and part of that will be determined as part of our joint study on the next generation transportation systems with DOD.

And in terms of our joint future study, we're looking at Shuttle II's, Son of Shuttle, the timeframe for that. We're looking at heavy-lift vehicle. Maybe unmanned heavy-lift systems. There's a big, fundamental tradeoff I think the Nation and our studies are going to have to address, and that is the role of rocket propulsion versus the role of airbreathing propulsion, which I think is going to need to be examined in this particular study.

Mr. Nelson. And you're going to address that in that joint study?

Mr. Moore. Yes, we are.

Mr. Nelson. And you'll report to us by December?

Mr. Moore. Yes. We're going to give you an interim report as we promised at that period of time.

Mr. Nelson. OK.

Mr. Moore. We also need not to lose sight of enabling technologies that would allow us to choose the appropriate path in this joint study. Enabling technologies like computer capability, like automation techniques, and so forth, that would allow us to reach capabilities that we have experienced now and know we can make some improvement in. So there are more technologies than just the propulsion or materials technologies we need to worry about.

And then finally I think I talked about the advanced goals or advanced missions. You know, undertaking a mission setting up a permanent base on the Moon or maybe going back to Mars, sending men to Mars. We need to think about that. Is that something this country wants to undertake as a singular challenge or is it an international undertaking? I think these are the kind of things that we need to think about as we move downstream.

I'm sure the National Commission will be thinking about that, and we're paying very close attention to what comes out of the Commission study and making sure we can respond to the kind of things that are determined by the important program, looking at the National Commission and looking at the future of this country in space.

That concludes these charts in a very hurried manner, Mr. Chairman.

[The charts referred to follow:]

OBJECTIVES

- EACH MISSION SAFE AND SUCCESSFUL
- MAINTAIN OPERATIONAL LAUNCH SCHEDULE
- REDUCE OPERATIONAL COSTS
- IMPLEMENT MANAGEMENT STRUCTURE FOR OPERATIONAL ERA
- COMPLETE STS DEVELOPMENT/EXPLOIT STS CAPABILITIES
- MAINTAIN A HEALTHY INSTITUTIONAL BASE
- DEFINE NEXT GENERATION SYSTEM

Continued Space Leadership for the United States

Figure 1

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GENERAL PROGRAM STATUS

- 20 SUCCESSFUL FLIGHTS COMPLETED
- ATLANTIS (4th ORBITER) FIRST FLIGHT OCTOBER 1985
- SECOND KSC LAUNCH PAD AVAILABLE JANUARY 1986
- VANDENBERG FIRST LAUNCH MARCH 1986

Figure 2

NASA OFFICE OF SPACE FLIGHT

ORBITAL CAPABILITIES

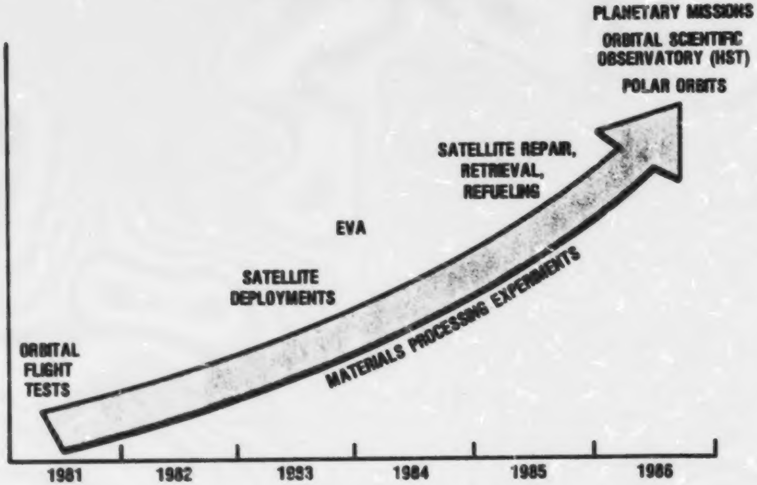

PLANETARY MISSIONS
ORBITAL SCIENTIFIC OBSERVATORY (HST)
POLAR ORBITS
SATELLITE REPAIR, RETRIEVAL, REFUELING
EVA
SATELLITE DEPLOYMENTS
ORBITAL FLIGHT TESTS
MATERIALS PROCESSING EXPERIMENTS
1981
1982
1983
1984
1985
1986

Figure 3

NASA OFFICE OF SPACE FLIGHT

OUTLOOK FOR STS

- **FULL OPERATIONAL STATUS**
- **REDUCTION OF OPERATIONAL COST**
- **24 FLIGHTS PER YEAR CAPABILITY**
- **CUSTOMER SERVICES**
- **FLEXIBLE MANIFESTING**
- **SYSTEM IMPROVEMENTS**
    - PERFORMANCE
    - ENGINE LIFETIME
    - AVIONICS

Figure 4

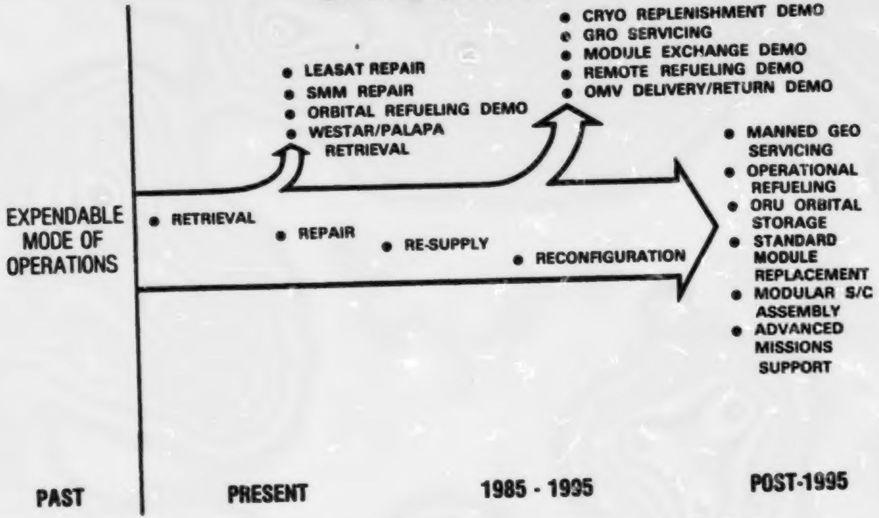
NASA OFFICE OF SPACE FLIGHT

LONG-RANGE PLANNING THRUSTS

- ORBITAL SERVICES
- SECOND-GENERATION SPACE TRANSPORTATION SYSTEM
- SPACE INFRASTRUCTURE
- LONG-RANGE MISSIONS

Figure 5

ORBITAL SERVICES



- LEASAT REPAIR
- SMM REPAIR
- ORBITAL REFUELING DEMO
- WESTAR/PALAPA RETRIEVAL

- CRYO REPLENISHMENT DEMO
- GRO SERVICING
- MODULE EXCHANGE DEMO
- REMOTE REFUELING DEMO
- OMV DELIVERY/RETURN DEMO

- MANNED GEO SERVICING
- OPERATIONAL REFUELING
- ORU ORBITAL STORAGE
- STANDARD MODULE REPLACEMENT
- MODULAR S/C ASSEMBLY
- ADVANCED MISSIONS SUPPORT

EXPENDABLE MODE OF OPERATIONS

- RETRIEVAL
- REPAIR
- RE-SUPPLY
- RECONFIGURATION

PAST PRESENT 1985 - 1995 POST-1995

42

Figure 6

Orbital Maneuvering Vehicle (OMV)

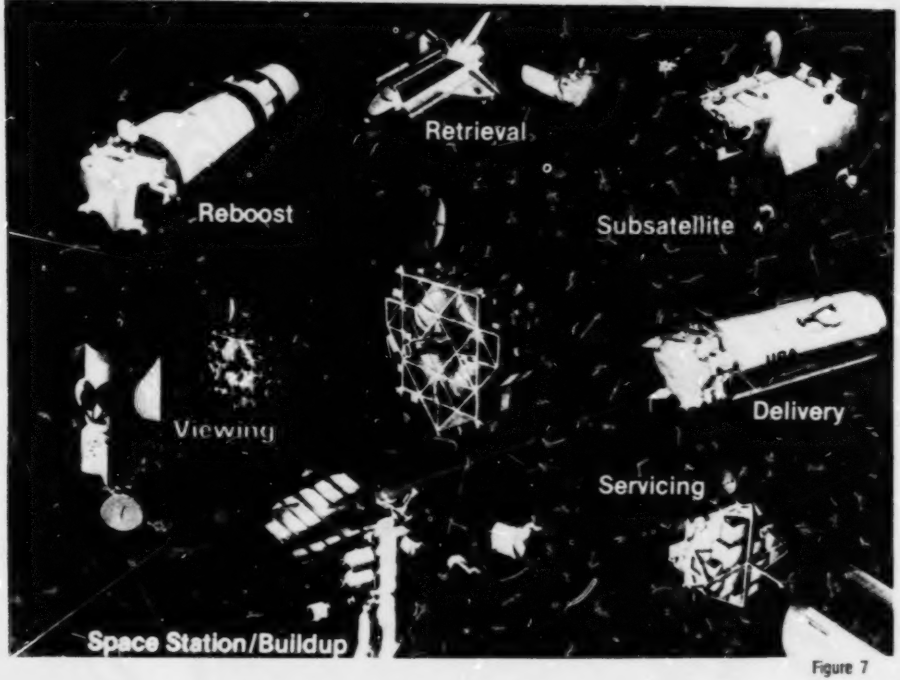

Retrieval
Reboost
Subsatellite
Delivery
Viewing
Servicing
Space Station/Buildup

Figure 7

NASA OFFICE OF SPACE FLIGHT

OMV

- REUSABLE REMOTELY-CONTROLLED VEHICLE
- [illegible] RETRIEVAL [illegible] CAPABILITY
- [illegible] TO 1500 nm [illegible] PLANE CHANGE
- PHASE B UNDERWAY
    - [illegible]
    - [illegible]
    - [illegible]
- [illegible] PHASE [illegible]
- [illegible]

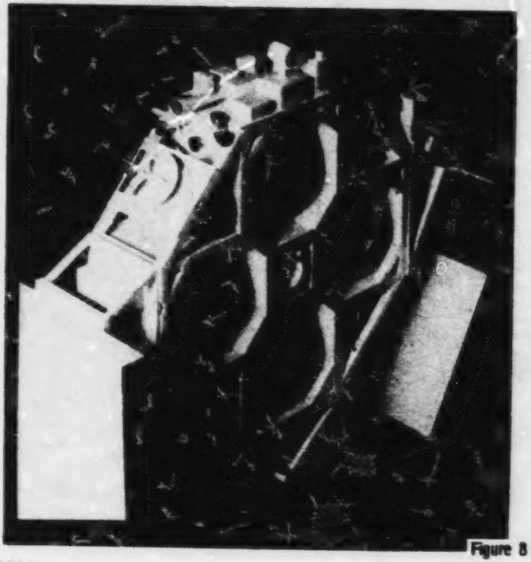


Figure 8

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SECOND-GENERATION SPACE TRANSPORTATION SYSTEMS

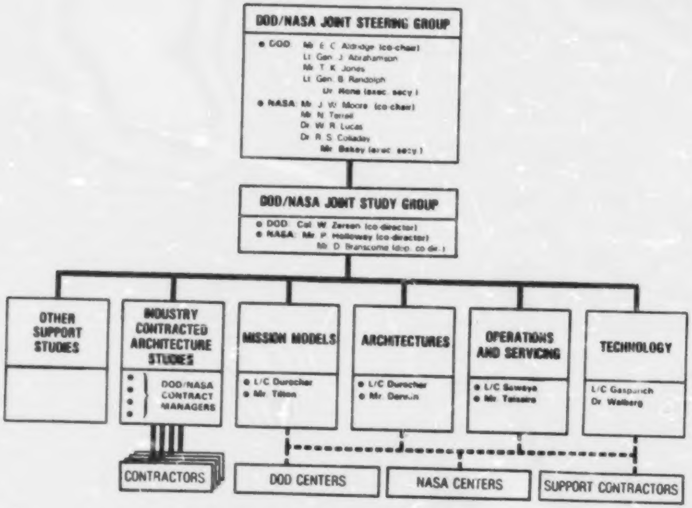
OFFICE OF SPACE FLIGHT

NATIONAL SECURITY STUDY DIRECTIVE
(PRESIDENTIAL APPROVAL 5/14/85)

- DOD AND NASA ARE DIRECTED TO CONDUCT A COMPREHENSIVE ONE-YEAR STUDY
- PURPOSE - "TO PREPARE THE U.S. TO MAKE IMPORTANT DECISIONS REGARDING THE SECOND GENERATION SPACE TRANSPORTATION SYSTEM FOR USE IN THE POST-1995 TIME PERIOD AND TO REVITALIZE THE NATION'S LAUNCH AND LOGISTICS/SUPPORT TECHNOLOGY BASE."
- PRINCIPAL END PRODUCT - "THE IDENTIFICATION OF ALTERNATIVE LAUNCH VEHICLE TECHNOLOGY DEVELOPMENTS DEEMED NECESSARY OR PRUDENT FOR THE POST-1995 TIME PERIOD TO MEET U.S. OBJECTIVES."

Figure 9

STUDY ORGANIZATION



DOD/NASA JOINT STEERING GROUP

- DOD: Mr E C Aldridge (co-chair)
  Lt Gen J Abrahamson
  Mr T K Jones
  Lt Gen B Randolph
  Dr Hone (exec secy)
- NASA: Mr J W Moore (co-chair)
  Mr N Terrell
  Dr W R Lucas
  Dr R S Colladay
  Mr Bekey (exec secy)

DOD/NASA JOINT STUDY GROUP

- DOD: Col W Zersen (co-director)
- NASA: Mr P Holloway (co-director)
  Mr D Branscome (dep co dir)

OTHER SUPPORT STUDIES

INDUSTRY CONTRACTED ARCHITECTURE STUDIES

DOD/NASA CONTRACT MANAGERS

CONTRACTORS

MISSION MODELS

- L/C Durocher
- Mr Tilton

ARCHITECTURES

- L/C Durocher
- Mr Derwin

OPERATIONS AND SERVICING

- L/C Seweye
- Mr Teisaire

TECHNOLOGY

L/C Gasparich
Dr Walberg

DOD CENTERS

NASA CENTERS

SUPPORT CONTRACTORS

46

Figure 10

NATIONAL SECURITY STUDY DIRECTIVE

TASKS

I. DETERMINE SETS OF POTENTIAL NEEDS, MODELS

II. DEFINE ARCHITECTURE(S) TO MEET NEEDS

III. IDENTIFY VEHICLE–INDEPENDENT TECHNOLOGIES

IV. DEFINE TECHNOLOGY DEVELOPMENT PLANS

Figure 11

ELEMENTS OF SPACE INFRASTRUCTURE

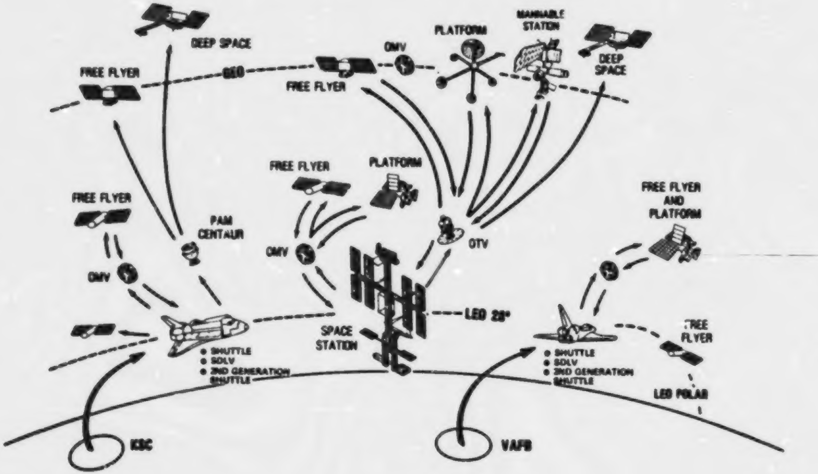

DEEP SPACE
FREE FLYER
GEO
FREE FLYER
OMV
PLATFORM
MANNABLE STATION
DEEP SPACE
FREE FLYER
PLATFORM
FREE FLYER
PAM CENTAUR
OMV
OTV
FREE FLYER AND PLATFORM
OMV
LEO 28°
SPACE STATION
• SHUTTLE
• SDLV
• 2ND GENERATION SHUTTLE
• SHUTTLE
• SDLV
• 2ND GENERATION SHUTTLE
FREE FLYER
LEO POLAR
KSC
VAFB

Figure 12

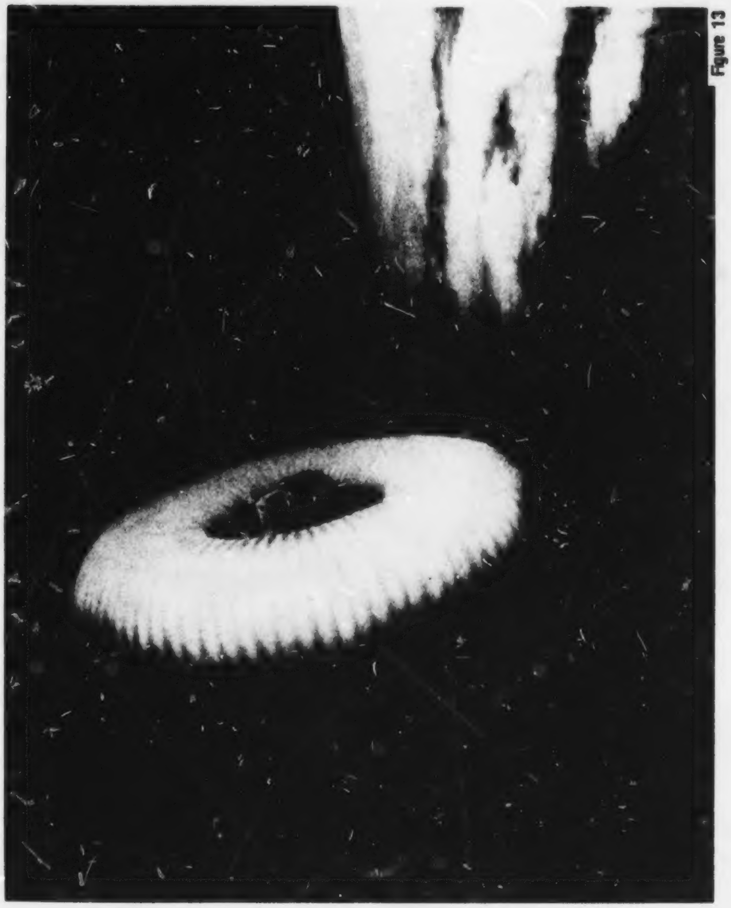


Figure 13

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NASA OFFICE OF SPACE FLIGHT

OTV EVOLUTION

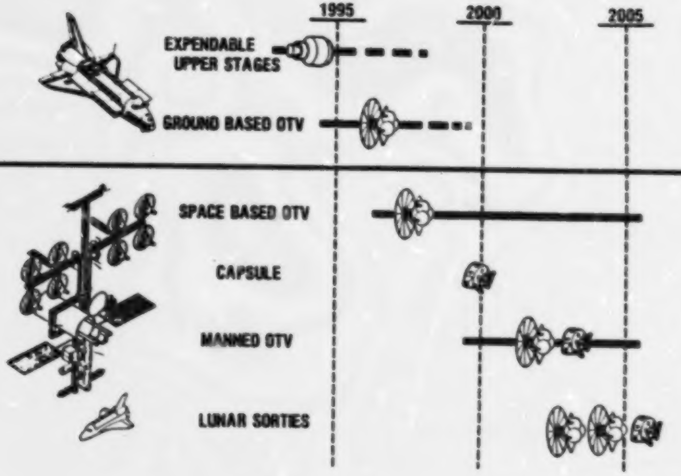
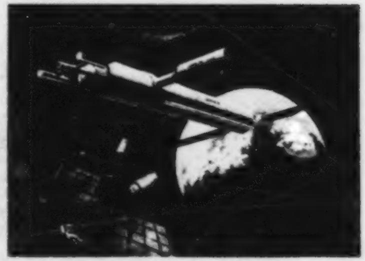


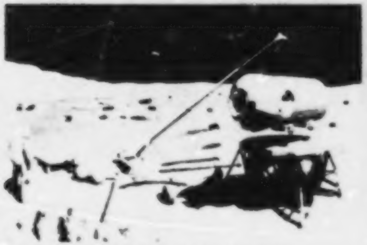
Figure 14

LONG-RANGE MISSIONS

POST—SPACE STATION MANNED MISSIONS



GEO OPERATIONS



LUNAR SURFACE ACTIVITIES

MARS LANDING

Figure 15

TECHNOLOGY NEEDS

TRANSPORTATION

- ADVANCED ENGINES (HYDROCARBON, CRYOGENIC, OTV)
- AEROBRAKES
- AUTOMATED/ROBOTIC GROUND PROCESSING/CHECKOUT/LAUNCH
- NEW PROPULSION CONCEPTS

ORBITAL SERVICING

- AUTOMATED RENDEZVOUS/PROXIMITY OPERATIONS AND SOFT DOCKING
- MAN-IN-THE-LOOP TELEOPERATION WITH STEREO COLOR VISION
- ROBOTIC MODULE CHANGEOUT EQUIPMENT

SPACECRAFT SYSTEMS

- HIGH STRENGTH/WEIGHT MATERIALS AND THERMOSTRUCTURES
- SPACE TETHER MATERIALS FOR ADVANCED APPLICATIONS
- AEROASSIST GUIDANCE AND CONTROL SYSTEMS
- AUTOMATION/ARTIFICIAL INTELLIGENCE ON-BOARD SYSTEMS

LIFE SUPPORT/CREW SYSTEMS

- LONG-DURATION, LOW MAINTENANCE CLOSED CYCLE SYSTEMS
- LONG-RANGE, HIGH ΔV MANNED MANEUVERING UNITS
- RADIATION PROTECTION FOR GEO, TRANSPLANETARY FLIGHT
- ADVANCED FOOD/WASTE/MEDICAL/HABITABILITY SYSTEMS

Figure 16

NASA OFFICE OF SPACE FLIGHT

LONG RANGE PLANNING ISSUES

- PLANNING FOR LOW OPERATIONS COSTS
- FULL EXPLOITATION OF SATELLITE SERVICING
- ORBIT TRANSFER VEHICLE-WHEN NEEDED?
- JOINT NASA/DOD STUDY ON FUTURE SPACE TRANSPORTATION:
    - SHUTTLE II NATURE AND CAPABILITIES
    - HEAVY LIFT VEHICLE-REQUIREMENTS AND TIMING
    - ROLES OF AIRBREATHING AND ROCKET PROPULSION
- EMPHASIS ON ENABLING TECHNOLOGIES
- ADVANCED GOALS/MISSIONS
    - MOON OR MARS OR COMBINATION
    - INTERNATIONAL PARTICIPATION

Figure 17

Mr. **Nelson**. OK. Dr. Colladay, if you could summarize your comments, and then we'll get into the meat of it with our questions.

STATEMENT OF RAYMOND S. COLLADAY, PH.D., ASSOCIATE ADMINISTRATOR FOR OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NASA, WASHINGTON, DC

Dr. **Colladay**. OK. Thank you, Mr. Chairman, I'll do that. If I were to come on last, after my colleagues from Space Science and Applications and Commercial Programs and Station and Transportation, I would tell you that the Advanced Technology Program serves as a foundation for everything that you've heard. I won't do that. Not because I'm not last, but because I think that by saying that it's a foundation it would overstate the role of the Advanced Technology Program by suggesting total coverage, when in fact our challenge is to invest in the right technologies that can enable a strong and innovative program in the future.

[Figure 1.]

I'd like to start with a chart that offers a window on our technology program through a set of missions that, while they're not approved, they are reasonable in a timeframe that we expect missions like this to be possible, and they gain position on this chart by virtue of the fact that they drive technology, provide a framework for focusing our program and thereby establish priorities in the technology effort. In transportation, and in spacecraft, in large space systems, you can see an array of mission driver programs that serve as the basis for focusing the technology that we invest in the program.

[Figure 2.]

Each of those, in turn, are backed up with a definition of the technology elements. For example, in space-based orbit transfer vehicles, which Mr. Moore referred to and Mr. Culbertson, the technologies that are key to the success of a orbital transportation vehicle would be aerobraking and space-based operations, reusable propulsion, and cryogenic fluid transfer.

[Figure 3.]

In each of those, if I look at that whole mission driver set, 90 percent of the technologies that we are pushing in our program collapse into five common areas. And by virtue of their commonality to a number of different missions, we can invest in what we think are the key enabling efforts that need to be addressed: propulsion, entry technologies, the precision control of large flexible structures, power, and space operations.

[Figure 4.]

In propulsion, we're working in both high pressure LOX/hydrocarbon and LOX/hydrogen, or hybred breed systems of the two, as well as airbreathing-to-orbit systems, transatmospheric vehicles, electric propulsion and OTV propulsion.

The fact that that engine in the lower right-hand corner that's a cartoon of an OTV engine, doesn't look like anything you've seen before simply suggests that we don't need to be constrained the way we have been in the past in the way we package engines, if we space base them and put them in a configuration where we can change out modules simply in a space environment.

[Figure 5.]

Following each of these five areas that are amplified in some detail in the Vugraph booklet that you have, I give a view of where we are today; working technology that will meet—come into fruition in the 1990's and follow that with a view of the 2000 timeframe and the 2010-plus timeframe. They give you a view on where the technology is directing us and when we think the payoff will be.

Obviously, in propulsion, the key is low-cost transportation systems, and that deals not only with chemical propulsion systems, but airbreathing-to-orbit and advanced, what we call breakthrough technologies, in laser propulsion, metallic hydrogen, and metastable helium, and things like that.

[Figure 6.]

Entry technologies cover the span from computationally intensive design capability and flow modeling to maneuvering entry vehicles and the aerobrake configuration for utilizing the atmosphere rather than propulsion for an OTV vehicle, which Mr. Moore referred to.

[Figure 7.]

Again the next chart illustrates the direction of the efficient use of entry environments through the timeframe of the 1990's to 2010. This chart (fig. 8) simply illustrates in a full-field view a type of orbit transfer vehicle that would make use of a heat shield and controlled re-entry for skipping off the atmosphere and back into a low Earth orbit.

Next chart.

[Figure 9.]

Large flexible structures is the third area of the five focused common technology areas. We have to be capable of working with large structures, their deployment, and assembly in space, advanced concepts; and once we have these large structures in space, to deal with their precision control, whether it be antenna or station or other large systems.

[Figure 10.]

The next chart simply illustrates the timeframe of deployable, distributed control systems on to a more routine assembly of large passive structures to finally the routine assembly and more manufacturing using extraterrestrial materials in space.

[Figure 11.]

The next chart shows, on the right, what we plan to do; and on the left, what we are already doing. As an example, the left shows the use of the orbiter as a research vehicle to gather important hypersonic and entry data. We've been actively using the orbiter for that purpose for sometime, and we plan to use the space station in the same way; as the best example we will have in the early 1990's of a large space structure that will be instrumented for research purposes.

[Figure 12.]

The next chart shows power as a key element of advanced technology in dealing with solar arrays, nuclear power systems, solar dynamic systems, and advanced batteries and thermal management that is an integral part of advanced power systems.

[Figure 13.]

The next chart shows the track through time of where power systems will evolve, and the parameter most descriptive of evolution of technology in this area is power level, from the 100-kilowatt level to megawatt to multimegawatt systems.

[Figure 14.]

The next chart illustrates a particular application of nuclear power systems for propulsion to the outer planets. The power system as shown there, the SP-100 configuration, does offer 100-kilowatt to megawatt capability.

[Figure 15.]

The next and final area of the five that I've illustrated is in space operations. In that area we're looking at artificial intelligence, expert systems, telerobotics and automation that can deal with the extensive operations that we're currently facing, both ground operations and potential on-orbit operations if we don't address system autonomy the way it has to be addressed, as well as telerobotics for satellite servicing and repair in orbit.

[Figure 16.]

Next chart shows, illustrates the timeframe again that as you go from the 1990's to post-2000 the key measure is increased autonomy and higher order artificial intelligent systems.

[Figure 17.]

The next chart illustrates the twin elements of our automation and robotics technology plans in the future, addressing both operations costs and capability for on-orbit operation.

[Figure 18.]

Illustrating that we need to utilize telerobotic systems in space for manufacturing and assembly. We have (fig. 19) a series of technology demonstration programs that serve as a nucleus and a magnet around which investigators and scientists and engineers can develop advanced technology for robotics.

[Figure 20.]

The next chart illustrates the use of cooperating telerobots that could go out from the space station and work on satellite repair and maintenance aspects.

[Figure 21.]

System autonomy is important from the standpoint of ground operations and operations in general as illustrated in that figure.

[Figure 22.]

And as in telerobotics, we have a series of demonstration programs that we'll begin in 1988 and follow for a decade around increasingly more complex automated subsystems and integrated systems.

[Figure 23.]

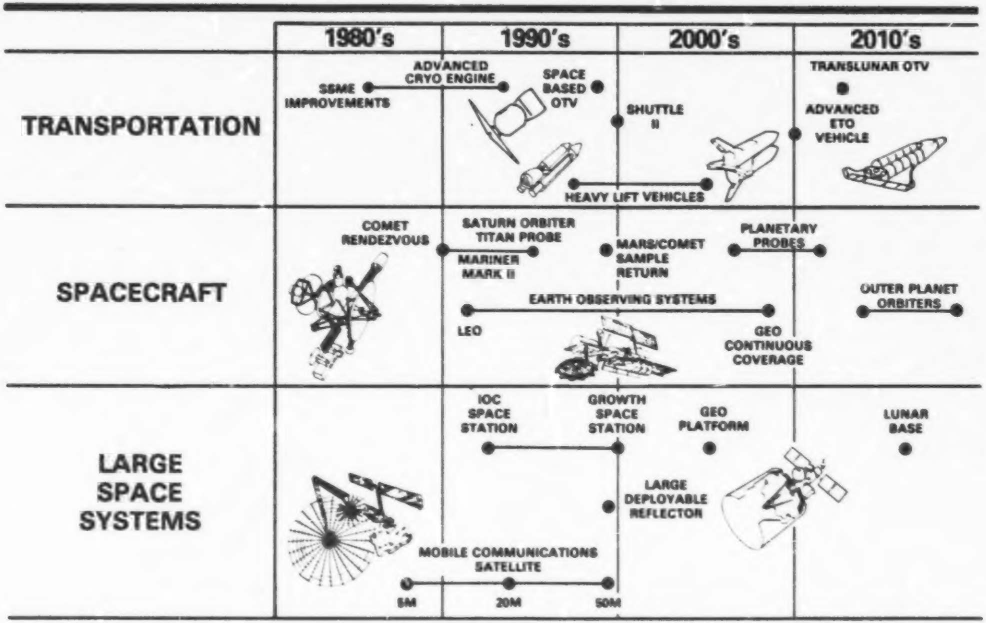
Finally it's becoming clear to us in the Advanced Technology Program that we need to extend our ground-based laboratories into space and to conduct research, technology, and engineering in space first with the space shuttle and then eventually utilizing the capability that the space station itself will provide for doing the engineering testing and building the data base that will be required in those cases where ground operation or ground testing in 1-G gravity fields is simply impossible. [Figure 1.]

Finally returning back to the focus that provides the framework for all of our advanced technology planning, this is the chart that I started with and conclude with. Thank you, Mr. Chairman.

Mr. NELSON. OK. Thank you, Dr. Colladay.

[The charts referred to follow:]

PROGRAM FOCUS ON DRIVER MISSIONS



1980's | 1990's | 2000's | 2010's

TRANSPORTATION

SSME IMPROVEMENTS — ADVANCED CRYO ENGINE

SPACE BASED OTV

SHUTTLE II

HEAVY LIFT VEHICLES

TRANSLUNAR OTV

ADVANCED ETO VEHICLE

SPACECRAFT

COMET RENDEZVOUS

SATURN ORBITER TITAN PROBE

MARINER MARK II

MARS/COMET SAMPLE RETURN

PLANETARY PROBES

EARTH OBSERVING SYSTEMS

LEO

GEO CONTINUOUS COVERAGE

OUTER PLANET ORBITERS

LARGE SPACE SYSTEMS

IOC SPACE STATION

GROWTH SPACE STATION

GEO PLATFORM

LUNAR BASE

LARGE DEPLOYABLE REFLECTOR

MOBILE COMMUNICATIONS SATELLITE

5M

20M

50M

NASA

OAST

RS85-348(1)

5 8

Figure 1

TECHNOLOGIES FOR SPACE BASED ORBIT TRANSFER VEHICLE

- AEROBRAKING
- SPACE-BASED OPERATIONS
- REUSABLE PROPULSION
- CRYOGENIC FUEL TRANSFER

NASA

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MISSION-COMMON TECHNOLOGY AREAS

- PROPULSION
- ENTRY TECHNOLOGIES
- LARGE FLEXIBLE STRUCTURES AND THEIR CONTROL
- POWER
- SPACE OPERATIONS

NASA

Figure 3

OAST
RS [illegible]

PROPULSION

LOX HYDROGEN

AIRBREATHING

LOX HYDROCARBON

REUSABLE EARTH TO ORBIT

ELECTRIC PROPULSION

OTV PROPULSION

NASA

OTV

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FUTURE: PROPULSION

ROUTINE SPACE TRANSPORTATION

- LUNAR-DERIVED PROPELLANTS (O_2, H_2 EXTRACTION)
- HIGH PERFORMANCE/HIGH THRUST PROPULSION SYSTEM
- ROUTINE TRANSPORTATION IN EARTH-MOON DOMAIN
  - "BREAKTHROUGH" SYSTEM (METALLIC H_2; METASTABLE He)

2010+

- AIRBREATHING EARTH-TO-ORBIT ENGINES AND FUELS
- FAIL-SAFE ROCKET SYSTEMS
  - HIGH PERFORMANCE/ MODERATE THRUST, NON-CHEMICAL SYSTEMS (NUCLEAR ELEC.; SOLAR/H_2)
  - LUNAR OTV

2000's

IMPROVED CHEMICAL PROPULSION SYSTEM

- LONG-LIFE EARTH-TO-ORBIT
- SPACE BASING

1990's

NASA

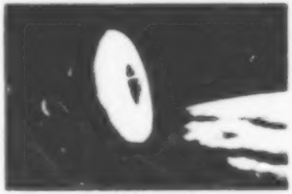
OAST
RP [illegible]

62

Figure 5

ENTRY TECHNOLOGIES

FLOWFIELD MODELING

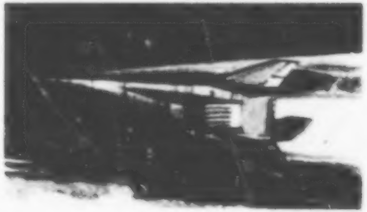


AEROBRAKING

AEROHEATING
AND AERODYNAMIC
PERFORMANCE

ADVANCED
THERMAL
STRUCTURES

MANEUVERING ENTRY



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FUTURE: ENTRY ENVIRONMENTS

EFFICIENT USE
OF
ENTRY ENVIRONMENTS

1990's

- AERDASSIST OTV
  - RAREFIED FLOW MODELING
  - REUSABLE, HIGH THERMAL LOAD TPS
  - ADAPTIVE GUIDANCE
- TRANSATMOSPHERIC EXPERIMENTS

2000's

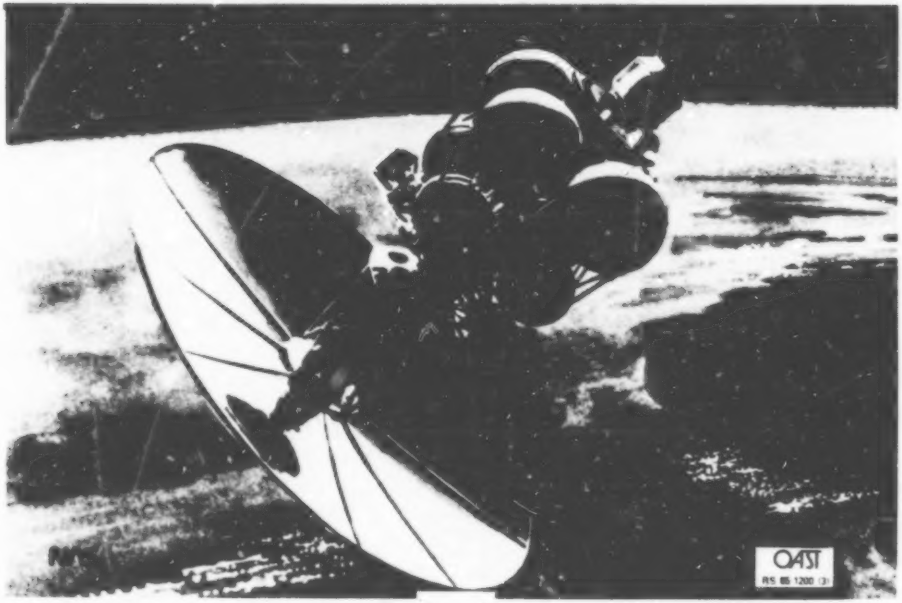
- PLANETARY AEROBRAKING
  - NONEQUILIBRIUM FLOW MODELING
- TRANSATMOSPHERIC VEHICLE
  - ACTIVELY-COOLED HOT STRUCTURES
  - LIGHT WEIGHT MATERIALS
  - ADAPTIVE CONTROLS
  - 3-D VISCOUS FLOW MODELING

2010+

- TRANSATMOSPHERIC TRANSPORT
  - INTEGRAL CRYO TANKAGE
  - LONG LIFE METALLIC TPS
- OUTER PLANET ORBITERS
  - MAGNETOHYDRODYNAMIC FLOW CONTROL

Figure 7

AEROASSIST
ORBIT TRANSFER VEHICLE TECHNOLOGY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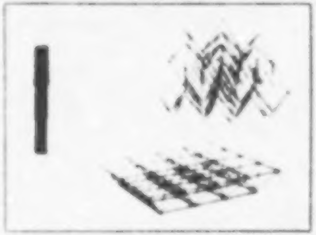
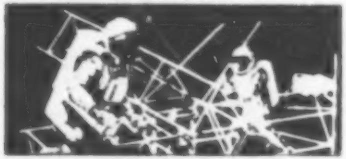
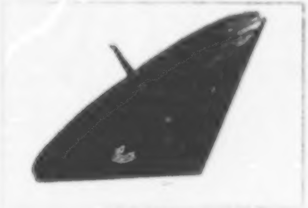
LARGE FLEXIBLE STRUCTURES AND THEIR CONTROL

DEPLOYMENT

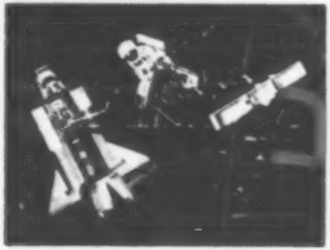


ASSEMBLY





CONCEPTS



DYNAMICS AND CONTROLS

NASA

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Figure 9

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FUTURE: STRUCTURES

ASSEMBLY AND CONTROL OF LARGE/COMPLEX STRUCTURES

- ROUTINE ASSEMBLY OF COMPLEX, ACTIVE STRUCTURES
- SPACE HABITAT CONSTRUCTION
- EXTRATERRESTRIAL MATERIALS EXTRACTION/PROCESSING
- LARGE HABITAT CONSTRUCTION

2010+

- ROUTINE ASSEMBLY OF LARGE PASSIVE STRUCTURES
- PRECISION CONTROL
- LIMITED FABRICATION
- LARGE HABITAT ASSEMBLY

2000's

- DEPLOYABLE
- DISTRIBUTED CONTROL
- MODULAR HABITAT ASSEMBLY

1990's

NASA

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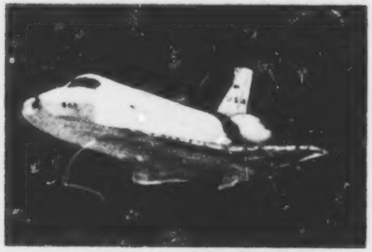
Figure 10

67

INSTRUMENTED SPACE STATION



ORBITER EXPERIMENTS PROGRAM

- RESEARCH QUALITY DATA
- VALIDATES WIND TUNNEL/ ANALYTICAL MODELS
- ALLOWS EXPANSION OF FLIGHT ENVELOPE

SPACE STATION EXPERIMENTS PROGRAM

- A LARGE STRUCTURES RESEARCH OPPORTUNITY
- REQUIRES DESIGNED IN INSTRUMENTATION

NASA

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RS [illegible]

POWER

LIGHTWEIGHT SOLAR ARRAYS

NUCLEAR

SOLAR DYNAMICS

Ni-H BATTERY

HIGH ENERGY REGENERATIVE STORAGE

LIQUID DROPLET RADIATOR

HIGH CAPACITY THERMAL MANAGEMENT

NASA

FUTURE: POWER

HIGH-CAPACITY UTILITY-TYPE SYSTEMS

MULTI-MEGAWATT

- MIXED SOURCES (SOLAR, NUCLEAR, CHEMICAL)
- UTILITY SERVICE
- TOTALLY SPACE/LUNAR BASED
- POWER DEPOT/POWER BEAMING

2010+

MEGAWATT

- LARGE PHOTOVOLTAIC ARRAYS
- DYNAMIC SYSTEMS (NUCLEAR)
- HIGH VOLTAGE
  - HIGH ENERGY, REGENERATIVE ENERGY STORAGE
  - AUTONOMOUS POWER MANAGEMENT
  - LIQUID DROPLET RADIATOR

2000's

HUNDRED KILOWATT

- DYNAMIC SYSTEMS (SOLAR)
- HIGH EFFICIENCY PHOTOVOLTAIC SYSTEMS
- LONG LIFE, REGENERATIVE ENERGY STORAGE
- AUTOMATED POWER MANAGEMENT
- THERMAL BUS

1990's

NASA

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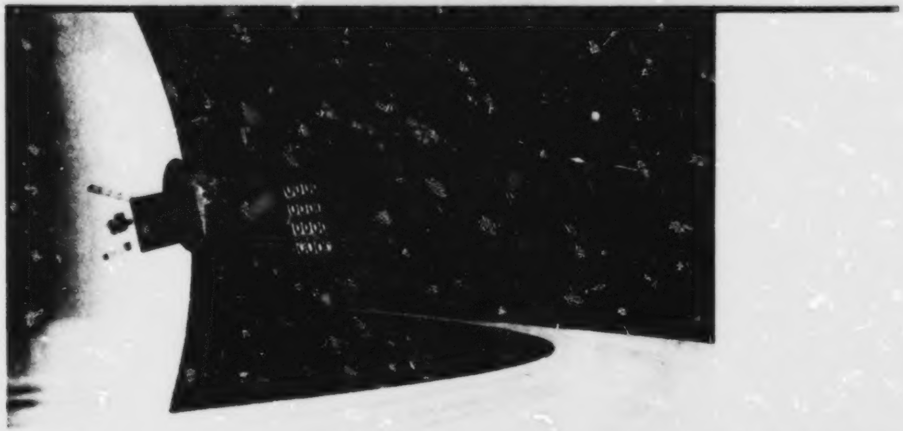
Figure 13

NUCLEAR POWER



HIGH CAPACITY,
LONG LIFE,
HIGH VOLTAGE
POWER

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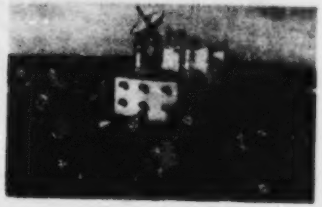
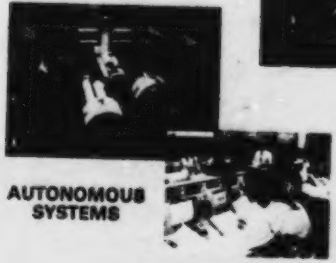
SPACE OPERATIONS

ROBOTIC SYSTEMS



HUMAN-MACHINE SYSTEM COMBINATIONS

DATA AND SENSOR SYSTEMS



AUTONOMOUS SYSTEMS

NASA

OAST

Figure 15

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FUTURE: SPACE OPERATIONS

ROUTINE MANNED AND ADAPTIVE UNMANNED OPERATIONS IN SPACE

1990's

- AUTOMATED FAULT DIAGNOSIS & MISSION PLANNING
- DEXTEROUS TELEOPERATION

2000's

- AUTONOMOUS TASK PLANNING AND EXECUTION
- AUTONOMOUS RENDEZVOUS AND DOCKING
- COOPERATING TELEROBOTS
- CLOSED LIFE SUPPORT SYSTEMS

2010+

- AUTONOMOUS SPACE OPERATIONS
  - MATERIALS PROCESSING
  - INTERNAL FAULT MANAGEMENT
  - SPACE SYSTEM DIAGNOSIS & REPAIR
  - ENVIRONMENTAL ADAPTATION
- LUNAR OPERATIONS
- AUTONOMOUS MARS ROVER

Figure 16

AUTOMATION AND ROBOTICS

REDUCE OPERATIONS COSTS

CAPABILITY

NASA

OAST

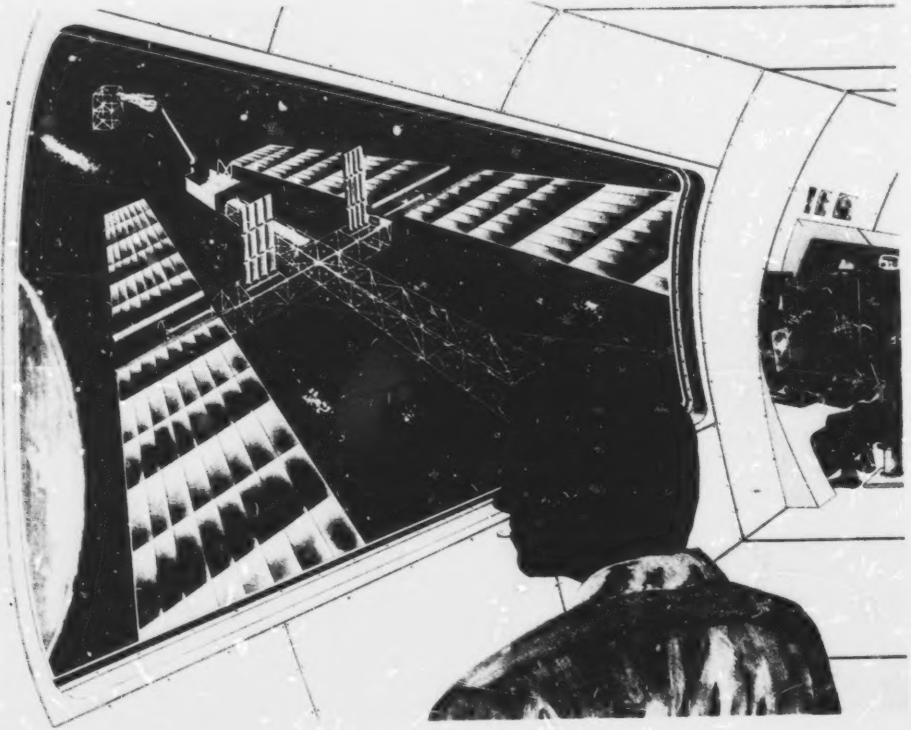


Figure 18

ROBOTICS DEMONSTRATIONS

- 1987 – STATIONARY ROBOT, SIMPLE SPACECRAFT SERVICING TASKS, SUPERVISORY CONTROL
- 1990 – FLIGHT VALIDATION, ORBITER MID–DECK
- 1990 – MOBILE ROBOT, SPACECRAFT SERVICING / RETRIEVAL, EXECUTIVE CONTROL
- 1992 – FLIGHT VALIDATION, ORBITER RMS
- 1993 – SPACE SERVICING AND ASSEMBLY
- 1994 – FLIGHT VALIDATION, OMV
- 1996 – UNPLANNED REPAIR REQUIRING FABRICATION
- 2000 – COOPERATIVE ROBOTS, GOAL DRIVEN COMPLEX TASKS

Figure 19

COOPERATIVE [illegible]

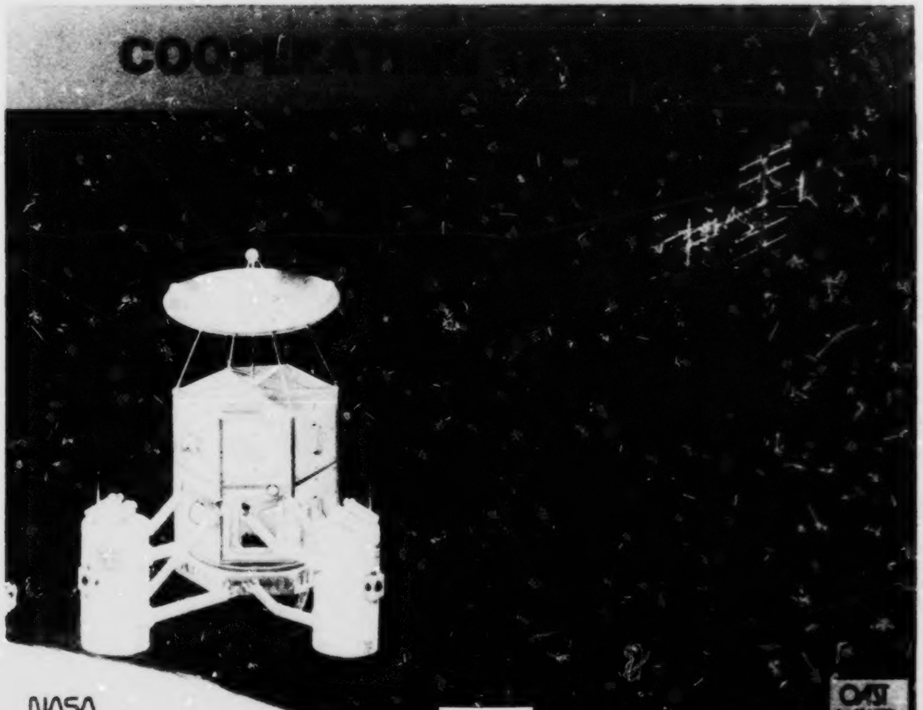
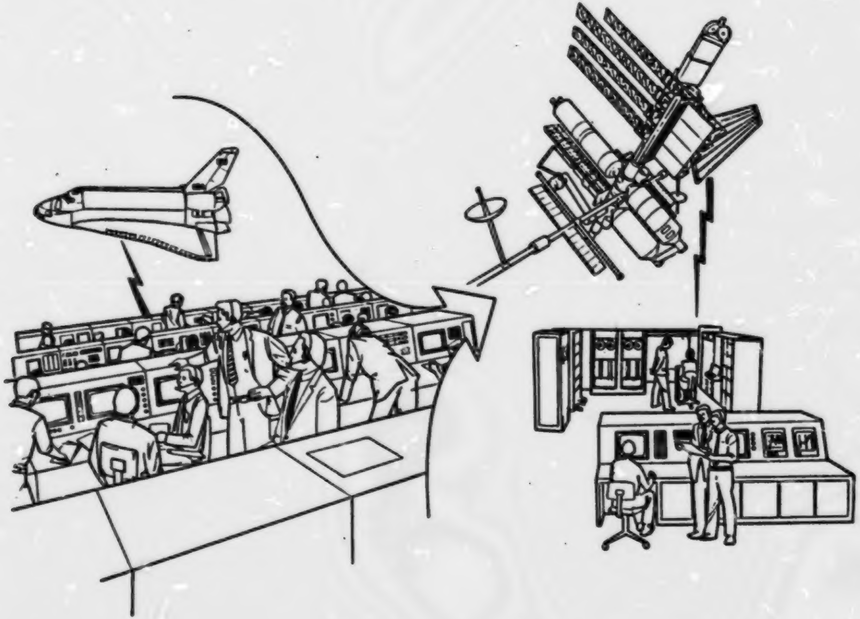


Figure 20

SYSTEM AUTONOMY



78 Figure 21

SYSTEM AUTONOMY DEMONSTRATIONS

- 1988 – INTELLIGENT ASSISTANT FOR GROUND OPERATION OF SINGLE SHUTTLE SUBSYSTEM
- 1990 – IN–SPACE INTELLIGENT ASSISTANT FOR SINGLE SUBSYSTEM
- 1993 – EXPERT SYSTEM CONTROL OF MULTIPLE SUBSYSTEMS
- 1996 – DISTRIBUTED EXECUTIVE CONTROL FOR SPACE STATION AND GROUND OPERATIONS

Figure 22

RESEARCH, TECHNOLOGY AND ENGINEERING IN SPACE

JOINT
GOVERNMENT/INDUSTRY/
UNIVERSITY
EFFORTS

SPACE-BASED RT&E

- **CONSTRUCTION OF LARGE STRUCTURES**
- **CONTROL OF LARGE STRUCTURES**
- **SPACE ROBOTICS FOR ASSEMBLY AND SERVICING**
- **CHARACTERIZATION OF SPACE ENVIRONMENTAL EFFECTS**
- **FLUID MANAGEMENT IN ZERO-G**

NASA

OAST

Figure 21

820

Mr. **Nelson**. Well, it's an exciting panel and it's an exciting subject. Indeed, Buck Rogers is here today. And now as we plan where you ought to go in the future is the subject of this hearing and we want to get into some of that.

Before I turn to Mr. Walker and Mr. Smith, let me just ask you to sort of project for us here, and then we will get into a lot of detail and we will get you all talking to each other.

Looking down the line, we've talked about shuttle II, we've talked about transatmospheric vehicles, and we have talked about heavy lift vehicles. Why don't you all elaborate on that, all three of you?

Mr. **Moore**. Well, let me start it off by simply saying that's obviously a major focus of the study that we're looking at right now. There's technology on the way that will support various of those particular vehicle studies, and I think, Mr. Chairman, before we really know what our focus is going to be, we're going to have to mate those kinds of capabilities with the mission needs as the various civil and military agencies define them. And that's what I'm looking at as far as my perspective on this whole thing is, is there a need? We believe there is. What's the timeframe for these vehicles? Do they all form some sort of a complementary system? That they're all phased in as a function of time according to some structured set of needs in this country? I think that particular feedback or that particular iteration to try to see if there's a match there, is a very fundamental part of our overall study.

And I would only add one other thing. I think we need to ensure that we are developing the technologies or at least identifying technologies, putting program plans together that will enable us to opt for any one of those particular systems or all of those particular systems. I can see needs for all of them, but I think it's a question of how we prioritize the mission needs, and so forth. So that's how I would comment on them.

Dr. **Colladay**. I guess I would comment——

Mr. **Nelson**. Let me interrupt you. Give me a concept of where you would use a heavy lift vehicle. You might want to comment about this with regard to the space station, which is an unmanned vehicle. The idea is to get it cheaply into orbit, and yet on a transatmospheric vehicle you might have the cheapness there. So why, if you've got an airbreathing engine, why are you talking about a heavy lift vehicle or—expand on that.

Mr. **Culbertson**. OK. I'm not sure whether I'm going to address the question in the way that you were thinking, but let me address it in this direction.

When we started the space station we recognized that we were limited, or we had the opportunity to use your space station——

Mr. **Moore**. Right.

Mr. **Culbertson** [continuing]. Space shuttle.

Mr. **Moore**. Space shuttle.

Mr. **Culbertson**. We sized everything so that it would be fit into this cargo bay of the shuttle and we would take it up piece by piece. And as we testified here 2 months ago, there's somewhere between 7 and 12 shuttle flights worth of hardware which will be required for us to assemble the space station that we're thinking of today.

Now, the shuttle lift capability didn't provide a severe limitation to us. It means that we will be assembling, it means we will create the large structures by unfolding or assembling piece by piece, but it really hasn't provided any major limitation to us.

On the other hand, we will use the space station to assemble those things which will go out of low Earth orbit and assemble them piece by piece. Clearly it's going to take a lot of work in space to assemble the large systems that will go to the planets, for instance. We should launch those systems out of low Earth orbit. We should not launch them from the ground assembled. We should be able to have a launch capability out of low Earth orbit because it is so much more efficient to go from there with larger systems. We can go out of low Earth orbit with fairly maximum thrust and work our way out to deep space. It is only then that you can consider the low thrust, very high efficiency systems which are associated with ionized mercury or ionized hydrogen, whichever you want to use; the electric propulsion that we've talked about so long; the solar cells that are very highly efficient. These low thrust systems can be used to get out of low Earth orbit and beyond but cannot be used to get into low Earth orbit from the Earth.

Mr. NELSON. Well, if we're going to assemble all of these structures, why do we need some huge, heavy lift vehicle? What's your thinking now? I know we don't have any definitive answers; I just want to know what your thinking is.

Mr. CULBERTSON. Well, from my standpoint, I have two needs I believe. First, our users find that the cost of transportation to get into space and get back out again, still is a very dominant part of their total cost. The commercial interests that we have, we'll consider that was a major, a cost.

Mr. NELSON. Sure.

Mr. CULBERTSON. And to reduce the cost into orbit is the first priority I think our users have.

The second thing is that the shuttle was designed without a space station—the presence of the space station makes a difference in the way one uses transportation in that the only way today that we can have a crew to check out a spacecraft, or repair or service, is to take the crew up and bring it back down again on that mission. Therefore, the high utility of the shuttle, to have a crew and its cargo there simultaneously is terribly important right now.

When we have a space station in orbit and crews in orbit constantly, that factor changes somewhat, and we must take that into consideration as we approach launch vehicles for crew and launch vehicles for transport. We can I think come up with, by the year 2000, with something that takes the maximum advantage of what we're going to put into orbit in the first part of the nineties.

Mr. MOORE. I just have one point, and then I'll ask Ray maybe to comment on technology. I think the fundamental question in this thing is can we lower the cost of getting payloads into orbit? That's what our real focus is, to try to reduce by an order of magnitude, or more if we can, getting the cost of cargo into orbit.

If someone has, and I believe there will be requirements identified to launch more than 100,000 pounds into low Earth orbit at some point in time in the nineties. The question is can we do that very cheaply as a single launch, or can we go up and assemble it in orbit? I mean both of those things are going to be looked at, and I think one has to understand where those kind of systems come into play.

And as far as airbreathing, I think, Ray, you can——

Mr. **Nelson**. Well, before we go to Dr. Colladay, it is conceivable, I mean it's not without the realm of imagination, is it, that you could have all of this combined into one vehicle? In other words, shuttle II, heavy lift and transatmospheric could all be one?

Mr. **Culbertson**. My thinking hasn't progressed to that stage yet. Maybe we could get there, but, at least as far as my thoughts are concerned, Mr. Chairman, I'm not convinced that they all marry together in a very efficient way at this point in time. I can see where you can carry that scenario to come up with one vehicle to do it, but I'm certainly not convinced at this stage of the game that that's the way it all should come out.

Mr. **Nelson**. Dr. Colladay.

Dr. **Colladay**. I would say that the answer to your question really will be driven by whatever system provides the lowest cost per pound of mass delivered to low Earth orbit. My objective is to make sure that the technology in airbreathing-to-orbit systems is matured enough to be able to compete in that scenario.

I, too, am not ready to claim that a single system would be the best approach. I think there might be a complementary system of heavy lift vehicles as well as airbreathing-to-orbit transatmospheric vehicles, but the key right now in my mind is to recognize that we have put airbreathing systems on the backburner for nearly 40 years, and I think we have to accelerate and mature that technology just to see how attractive that option really is. If it delivers the lowest cost to orbit for a delivery system, then it will win. It will be the preferred approach.

Mr. **Nelson**. Dr. Colladay, we haven't gotten into this—Jim Beggs mentioned it in his opening testimony—but you're the Associate Administrator for aeronautics. Why don't you just take a moment here and get everybody excited about the Orient Express, 2-hour flight for commercial passengers from here to the Orient?

Dr. **Colladay**. Well, I think the technology that we've been alluding to as airbreathing-to-orbit can totally change the way we look at space—at air transportation systems and aviation in general. I think it offers the potential. It's so dramatic and so revolutionary in the capability that it offers that it could allow this country to totally skip the supersonic transport-type aircraft. In looking at what the times for trans-Pacific range trips would be, from Los Angeles to Tokyo in 2 hours, the productivity is there for a Mach 6 to Mach 12 transport that makes that payoff where the Concorde and supersonic at Mach 2 to 3 range simply don't pay off economically the way a hypersonic transport would.

It's the same technology that needs to be developed for a civil transport version as what we need to develop in airbreathing-to-orbit systems. Rather than going to Mach 25 and orbital velocity, we designed a transport for Mach 6 to 12 hypersonic cruise for going anyplace between two points in the world in a matter of an hour or two rather than the 747 trip from Los Angeles to Tokyo in 12 hours or more.

Mr. NELSON. You guys must have some of the most exciting jobs in the Federal Government. Here Mr. Culbertson's talking about all of this national laboratory in a station and Mr. Moore and Dr. Colladay are talking about transatmospheric vehicles that if you want to rev it up to 5 Mach you can go 2 hours to Tokyo, but if you want to go to 25 Mach—Mach 25 you can insert into orbit in a single stage. So that's pretty revolutionary and pretty exciting.

Mr. CULBERTSON. Could I ask——

Mr. NELSON. I'm going—yes.

Mr. CULBERTSON. While you've got their attention, those of you who are in charge of technology and transportation, I'd like to put a plug in for another attribute for the machines you're talking about. And that is to get closer to what we would call a launch-on-demand capability. One of the problems that we face today is the long leadtime that's necessary, long queue time for getting on the shuttle. You know, we can live with that and we are living with it fairly easily, but it is one of the characteristics of space transportation that is a severe limitation today. You ought to keep that in mind as you plan whatever it is you've got in mind.

Mr. MOORE. Well, I think that's something that we ought to keep in mind for the current shuttle program. If you notice one of my charts, one of the objectives is to achieve more flexible manifesting and more responsive manifesting. I think in the future we need to look at the ground system and the ground OP's integral with whatever vehicle system concepts we come up with, and we're planning to do that as part of this overall study.

Mr. CULBERTSON. I'm talking about an order of magnitude, Jesse.

Mr. MOORE. I understand that. You bring the cargo there, Phil, we'll launch it.

Mr. NELSON. Well, let me contain my enthusiasm here and allow that enthusiasm to be distributed among my colleagues here.

Mr. Smith.

Mr. SMITH. I really don't have any specific questions, Mr. Chairman, but NASA sounds so exciting I think we should encourage all of our opponents and potential opponents to join NASA and get involved in all this excitement and not run for Congress. [Laughter.]

I thought Congress was the most exciting but I'm beginning to have some second thoughts.

I guess just a general comment in the form of a question is I have to hand it to you. I mean, I don't know how you prioritize the unknown, which is really what you're doing. It's amazing. I mean, I had not heard specifically about the Orient Express. I'd be interested in knowing what it's going to cost each one of us——

[Laughter.]

Mr. SMITH [continuing]. To go onboard, if you have any ideas about that, whether or not it's economically feasible. Obviously it's technologically feasible. Is it economically feasible?

Dr. COLLADAY. Oh, I think it'll be economically feasible because of the productivity offered by equipment that could make that trip in an hour across the ocean and return and make another trip and return——

Mr. SMITH. How many people onboard?

Dr. COLLADAY. Well, you're getting into point designs of the vehicle that are way beyond where we are now. But it would be a typical large transport aircraft size. On the order of 150 to 200 passengers is not unrealistic.

It would most likely be hydrogen fueled, cruise at Mach 6, once you get above Mach 6 you might as well go Mach 12. You've pushed the longest part of the trip to that of going to and from the airport, rather than the cruise part of it.

Mr. **Smith**. I know that it's been touched on to some extent by Mr. Beggs' testimony, but in terms of criteria for—the criteria that you use to prioritize, there are so many things going on. I mean, it's just incredible. There's nothing like it in any other field. I mean, you can explore Mars or you can go on out, out of the solar system or you can concentrate on experiments that are going to help in medical research—I mean, you can just go on and on. Or you can, you know, put your space station up and, as Mr. Walker talked to you, the power sources. There are so many things to do.

How do you prioritize? You must have some monumental, colossal discussions—arguments, if you will—in terms of what ought to be the priority. I just am curious as to how you, how you come up with the things that we've seen here today, the Buck Rogers technology and all. I mean, how do you—how do you do this? How do you prioritize that?

Mr. **Moore**. Well, you've seen three of the major program elements in the agency here this afternoon—the Space Station, Aeronautics and Space Technology, and Space Flight—and I think you will also see Office of Space Science and Applications. A number of us have different advisory groups that look at what we're doing. We review with them the kind of programs we're working on. They come back, based on a set of needs and talks about the importance of various things as a function of time.

We also work with other agencies. For example, the study I'm involved in with the Department of Defense is also soliciting requirements from other agencies in the Government to say we need to have this kind of a mission capability by this point in time. Our job then is to see what's possible to implement based on the timing required. Then we have a funding limitation that we obviously try to match these particular efforts with. Then they all come together as part of the agency's budget process, and the ultimate priorities are set by the Administrator based on guidance that he gets from NASA advisory councils and other groups of people that are working in the program.

Mr. **Culbertson**. As far as Mr. Moore's and my programs—20 years ago when the National Commission, or the President's Commission was set up to study the future of the program, they looked upon a transportation system and a permanent manned capability in space as the two highest priority capabilities to develop. You see, Jesse's got a transportation system. I'm building the facility; And both of them enable a vast array of other things to be done. Both of us will support science. Both of us will support the private sector for their opportunities to get in and use space on their own in commercial endeavors. Both of us support the opportunities for Dr. Colladay to conduct research and advanced technology work because he gets research out of the shuttle as an aeronautical vehicle, he will get research out of the space station as a large flexible structure, and he will take advantage of us both in my understanding, for advanced operational concepts.

So that both the two programs that you talked about today open vast new doors for other kinds of opportunities to take place in space, and one of those will be science. You'll hear more about science and applications. You'll hear more about that tomorrow.

So the two things, transportation and the laboratory in space, have for a long time been goals that NASA had, and they have risen in priority until we now have both of them; one in operation and one being developed. So I think those were fairly natural because they enabled us to do so many other things.

Dr. **Colladay**. The strength of the program I think rests in the fact that there are more good ideas than we can afford to fund, and the competition for those, for the resources, is so severe that only the best programs survive and are funded. The things that are littered on the floor are themselves good ideas. The weeding out process and the advisory committee structure that we rely on so heavily in the process of long-range planning that we go through is intense and it results in the best of the best programs being supported.

Mr. **Smith**. We've seen a smorgasbord, if you would, array of items over the past several weeks and months here in the committee, and some today. Is it fair to say that no one element has won out in terms of dominance? I mean, say, manned exploration of the planets versus, you know, scientific research? Are we still looking at—are we still going to continue to look over the next 20 years, 30 years at a variety of things like this? Are we going to begin to zero in on—I mean, is there a policy? Is somebody out there pushing manned—manned exploration versus some of the other things?

Dr. **Colladay**. Well, Mr. Beggs referred to in his statement a balanced program. I know that's an imprecise term and we probably overuse it, but I think it is just that. We're not taking a shotgun approach and doing a little bit of everything. We're targeting the opportunities where the benefits are. I wouldn't say there's an emergence of any single element of the program dominating over the other, and I don't think there should be.

Mr. **Smith**. I don't, either.

Mr. **Moore**. Well I agree totally with that. I think Ray is right. Mr. Begg's commented on that. I think if you talk to an individual in a given program area, for example, in space science, he would tell you or she would tell you that we're not spending enough money in the agency. You do the same thing in technology you'd probably get the same answer. I think we do have a reasonably balanced program, and I think that's where Mr. Beggs plans to continue the agency in the future, with as much balance as we can among the various program officers.

Mr. **Smith**. Thank you. Thank you, Mr. Chairman.

Mr. **Nelson**. Mr. Walker.

Mr. **Walker**. Thank you, Mr. Chairman.

First of all, maybe it's a bit of a debate between Mr. Moore and Dr. Colladay, but do you see any kind of incompatibility between a shuttle II concept and the airbreathing-to-orbit concept? I mean is there any basic incompatibility that you see between those two?

Dr. **Colladay**. I don't see any incompatibility.

Mr. **Moore**. At this point in time.

Dr. **Colladay**. I think shuttle II could be an airbreathing-to-orbit system. It may be a——

Mr. **Moore**. Rocket system.

Dr. **Colladay** [continuing]. A rocket system. It may be primarily a people transporter and companion——

Mr. **Moore**. Right.

Dr. **Colladay** [continuing]. As a companion to a heavy lift launch vehicle. It might be a single vehicle that's airbreathing-to-orbit. We really don't know and the measure is going to be what delivers the lowest cost——

Mr. **Moore**. And something that——

Dr. **Colladay** [continuing]. Payload.

Mr. **Moore** [continuing]. We can turn around very quickly; carry specialized cargoes, people and so forth. At this point in time, Mr. Walker, I wouldn't say there is a conflict. I think as we get more maturity in looking at these particular things, I think they'll become clearer in terms of what is the appropriate approach to take along these lines.

Mr. **Walker**. OK. Did I gather from both of you, then—I gathered a little bit of reservation when the chairman suggested putting all three concepts together. Do I gather, then, that the one that you would separate out from those would be the heavy lift vehicle? That you think that the scramjet might not provide us with a—with enough heavy lift capability——

Dr. **Colladay**. I think it would be very unlikely to see a scramjet propulsion vehicle that was able to lift heavy payloads to orbit.

Mr. **Moore**. Right.

Dr. **Colladay**. You can—I can——

Mr. **Moore**. I would agree with that.

Dr. **Colladay**. [continuing]. I can see a shuttle class vehicle or smaller. I really don't think we will see an airbreathing-to-orbit vehicle that would be in the——

Mr. **Moore**. Right.

Dr. **Colladay** [continuing]. Heavy lift class. I might be wrong. But the integration and the thrust levels required in this overall structural efficiency——

Mr. **Moore**. Right.

Dr. **Colladay** [continuing]. Of a transport system like that appears to me to be beyond the foreseeable future of technology.

Mr. **Walker**. Was that essentially your reservation, too?

Mr. **Moore**. I certainly agree with that. I think Ray is right on track. I don't think we want to rule that out, but I think it's premature to say much in a positive sense about rolling all these ideas into one.

Dr. **Colladay**. If the scramjet propulsion system and the integration in the whole vehicle, transatmospheric vehicle, prove to be as effective as I think it will, we will not keep those out of the launch vehicle system.

Mr. **Walker**. Right.

Dr. **Colladay**. It will change the way we look at not only aeronautics but in access to space, too.

Mr. **Moore**. Yes.

Mr. **Walker**. Which I think is what we find exciting about the whole concept as well.

Mr. **Moore**. No question about it.

Mr. **Walker**. Mr. Culbertson, I appreciated your explanation about the—how the business of the designs ends up changing as you learn new things and so on, and obviously that is what we want to be happening. I guess my concern and what I was trying to express was it seems to me, though, that there is a fundamental decision that is made as to whether or not you have power on the station or buy power from off the station. And all the concepts that I have seen indicate that the decision has already been made to have the power aboard the station, which it, you know, and so that what I'm—I guess some of my questions are why has that very fundamental decision been made along the line if, in fact, there are other kinds of ideas being floated that seem to me to at least have some engineering feasibility to them?

Mr. **Culbertson**. Well, there are two problems that I see with a commercially supplied power system. One is—and when I say—I'm reflecting how you defined it; and that is that perhaps a separate spacecraft.

Let's first talk about a separate spacecraft. The problem of transmission of that power to the space station is not a trivial technical problem because it will probably be a microwave system in which the size, the receiving antenna would be very, very large for the kind of power that we're talking about, and the proximity operations or the coorbital flying of those two for continuously is not an impossible technical task, but it's not a trivial problem at all. We have not transmitted that kind of power in space at all, over any kind of distance at all.

The possibility of a private corporation providing a power system which is attached to the space station as is the one that I illustrated or in some other way poses no new technical problem. The problem that I see is one—two. One, that nobody has suggested, has come up to me and suggested that—would we be willing to back down from the power—from developing that power system in the Government and let the private sector do it. That's the principal reason.

And I think that the reason that we haven't had any serious proposal at all in that respect is that—comes back to the thing that Mr. Beggs said. That the things that the Government probably ought to invest in are those which are beyond—which have a leadtime or a size of investment which does not make that kind of investment very attractive for the private sector.

Mr. **Walker**. Well, but of course, and it's a part of a discussion we had here the other day. The attractiveness of the investment depends very much upon the predicted profitability of that which you fly. If, in fact, the Government was assuring a private concern that it was going to buy power from that station, then all of a sudden you change the investors' attitude toward putting their money into such a station.

Mr. **Culbertson**. Yes.

Mr. **Walker**. That, you know, if, in fact, there is a—not only an implied market but a real market there, then—then it seems to me you might begin to hear from a number of people that would have some ideas as to how to do that. They might be coming through your door so long as they think you are going to fly your own power source. And that's kind of the skinny within the community. There's probably nobody out there that's going to come to you and suggest to you that we can fly power source because, in all honesty, given that scenario they couldn't find the investment dollars——

Mr. **Culbertson**. Well, I've——

Mr. **Walker** [continuing]. To build a substation.

Mr. **Culbertson**. I've spent a long time talking to both the aerospace industry and the investment community about urging people to come to me and propose to develop and lease to us or provide services to us for a fee any part of the space station that they want to consider. I have honestly done that with every contractor that we have who is working on it and with those contractors who weren't working on it, and I have not had anybody propose such a venture.

Now, and as I have said that, I have indicated that I would be able to withdraw, or propose to withdraw the Government from any of these pieces as long as we had a reasonable technical arrangement.

Mr. **Walker**. Sure.

Mr. **Culbertson**. If they had an approach to give to me.

Mr. **Walker**. OK. To go to the technical question just briefly. When we did the studies on space station, it seems to me that we ran into questions as far as cost and a number of other major hangups on space station. But I was under the impression there that there were no major technical problems. There indeed were technical hurdles to go over, but there were no major technical problems in terms of the microwave function. Is that a wrong perception?

Mr. **Culbertson**. Well, I'm not familiar in detail with what you are talking about, but the problem is somewhat different in that we are talking about radiating toward a manned spacecraft with reasonable limits in the size of the antenna that we would have. I have not seen any definitive studies which say that, that it is impossible. It is more, I think more of a technical problem than the problem which is posed from generating power in a geostationary orbit and transmitting it down to a large land-based antenna.

Mr. **Walker**. Is Astrotech one of the people that you've talked to about, about the potential of contracting for power?

Mr. **Culbertson**. I have talked to some people who are associated with Astrotech. I haven't made any kind of formal offer to them.

Mr. **Walker**. They're quoted in an article that I have here as being people who are talking——

Mr. **Culbertson**. Um hum.

Mr. **Walker** [continuing]. About that. It seems that that's the kind of thing. That was in USA Today evidently in a recent article.

Mr. **Culbertson**. Well, I've made that offer for the last year and a half, or encouraged people to try to come to me, and I will continue to do so until we start to do a detailed design.

I think it is important. I welcome the concept that is proposed by Space Industries, Inc. because I think that is a very logical attribute and a complementary piece of the infrastructure for the space station. I have looked forward to people proposing things on the ground which might be complementary to the overall program.

We are in all of these cases talking about hundreds of millions of dollars of investment.

Mr. WALKER. Mr. Chairman, if I could ask unanimous consent to include that article in the record at this point.

[The article follows:]

THE FIRST UTILITY IN SPACE?

A Pittsburgh firm wants to be the first power company in outer space.

Space Shuttle of America Corp. proposed the idea Friday as a necessary "move from the role of space traveler to the role of space resident."

The power station would:

Allow the space shuttle, now limited to eight days in space, to remain aloft indefinitely. "The shuttle would come along, attach a tether to it and refuel," said Peter Glaser, an Arthur D. Little consultant.

Serve the electricity needs of USA companies manufacturing phramaceuticals and other products on an orbiting space station, scheduled by NASA to be launched in 1989.

Ultimately the station could even provide electricity on earth "to as much as an entire nation," said Willard Rockwell Jr., chairman of Astrotech International Corp., parent company of Space Shuttle of America.

The first power station, however, probably would be a 7- to 20-kilowatt unit, roughly 30 feet wide and 100 feet long capable of serving the shuttle and a space industrial park.

Eventually, that and other businesses supporting the park will constitute a $10 billion industry, Glaser said. "We're seeing the first steps toward a space industrial infrastructure. You might call this the 'Orbital Power and Light Co.' "

It's uncertain whether the power station would use solar, nuclear or some other energy source, Glaser said. A study on the technology and costs will be completed by year end.

Meanwhile, Rockwell will be trying to persuade NASA to let his company own or operate a space shuttle. "We're pushing them as hard as we can."

Mr. WALKER. A couple of other questions. And maybe it's because this is implied, but I was somewhat interested when you showed your chart about the space station functions that one of the functions that was not listed on there is as a habitat. Now maybe that's because it's implied when you say permanently manned station. But it seems to me within the user community that is one of the principal functions they see for space station. That a lot of them may not have any great need to be aboard space station to fly their actual work, but if, in fact, the space industrial park is to be a reality that one of the major functions of the space station is to have a place for their people to be aboard so that they can in fact go out and do work in shirtsleeve environments in the modules that you showed as being supplemental to the space station.

Mr. CULBERTSON. Well, I hope that that is implied. I didn't say it, you're right. But certainly we would expect to do the same kind of thing that we have in the space shuttle. That if the user's crew can do a more effective job in the things they want to be done than—with their own crew, then certainly we ought to be able to entertain that.

Mr. WALKER. But doesn't it become important to some extent as to how we visualize this? Because, in fact, if what you are building is a facility which is essentially an industrial facility, a laboratory facility, an observation facility, all the things that you had up there, and the people who want to use it essentially see it as a habitat where they're going to move people in and out of it and so on, that does change the baseline of the design to some extent, doesn't it?

Mr. **Culbertson.** I don't think it changes the baseline of the design, but if it's not apparent, we should make it apparent. I agree with you.

Mr. **Walker.** Finally, as I understand the working that's going on right now, the space station is designed for about 75 kilowatts of power.

Mr. **Culbertson.** Yes.

Mr. **Walker.** Is that correct?

Mr. **Culbertson.** That's the present baseline.

Mr. **Walker.** I have also understood that about 50 kilowatts of power, then, are planned to be used for scientific purposes.

Mr. **Culbertson.** But 50 kilowatts—well, no. Fifty kilowatts of power of that 75 are planned for users, but that's both scientific and applications, and in the commercial use that takes place on the manned system.

Mr. **Walker.** How much of that power is reserved for commercial users other than international?

Mr. **Culbertson.** I haven't got at my fingertips specific allocations for that. I can let you know what that is.

Mr. **Walker.** I'd appreciate it. And I'd appreciate having it for the record.

[The information follows:]

The Reference Configuration for the Space Station Manned Element calls for an Initial Orbiting Capability (IOC) of 75 kw total. The Manned Element is assumed to use 25 kw for housekeeping, making 50 kw available for national and international users. We anticipate that the percentage of this 50 kw dedicated to any specific class of user will vary with time and we are working in Phase B to define the Space Station as a facility that will support changing complements of users. We are now working with information about the types of activities which users would like to pursue at IOC, but it will be some time before the users begin to solidify their planning and are ready to start payload development. Until this occurs, we will not be able to specify the exact percentage of resources that will be provided to U.S. commercial users.

Mr. **Walker.** Because one of the concerns that I'm hearing is from people who think that the power allocation set asides, if you take what's there for scientific, plus put that with the guarantees that we've given to the international community in order to get them aboard, that there is very little power left and may be insufficient power for any commercial user to run a furnace aboard the station.

Mr. **Culbertson.** Well, we haven't made any guarantees to the international community on any power level.

Mr. **Walker.** But certainly, if Japan and Germany and some of these people are flying, they think that they're going to get some use of that.

Mr. **Culbertson.** Oh, yes.

Mr. **Walker.** And the feeling is—the feeling is among our commercial community is that the main thing that they're going to be interested is probably flying some kind of a furnace themselves. That they see that as we do, one of the major opportunities for the future. If, in fact, they end up being the people drawing down a good portion of the power because of flying their furnace, then it becomes somewhat critical to our commercial community to understand what may be available to them.

Mr. **Culbertson.** Sure. I understand that.

Let me tell you how we're approaching the question of furnaces as a specific example. In our discussions with ESA and Japan, both of whom are interested in building a laboratory and both of whom are interested in materials processing as well as other kinds of things to be done in those laboratories, we have made the point as clearly as we possibly can that the space station must be developed as an integrated whole. That is, we must all assume that the provisions which are provided in laboratories are available to all parties. We will in that way strive to avoid duplication to the degree that we possibly can. That is, we have assured ESA and Japan and Canada that they will have access to our laboratories and that we will expect in a reciprocal way to have access to their laboratories.

It is my belief that they understand that very clearly. It wasn't clear to them at the start of the program, but we have talked about that enough that it is clear to me they at least understand that that is the principal on which we intend to proceed.

There are going to be some limitations in the resources that we have. Power is one of them. I think we will be more limited in the crew size, as a matter of fact, to the availability of crew than we will power. But power comes a close second, and laboratory volume is the third, which I believe we will want to add capability as rapidly as we can. I think we're sized about right now for our understanding of it. The 75 kilowatts is equivalent to the total power that we've put into space in the history of the Space Program. The power to the users in the space station will be about—well, what do you have for users?

Mr. MOORE. Well, we've got—

Mr. CULBERTSON. Up to 10 kilowatts?

Mr. MOORE. Roughly 10 or 12 kilowatts.

Mr. CULBERTSON. We'll have five times more the power and it'll be available 365 days of the year rather than the time that the shuttle has. So that the step function in power which is provided by the station beyond that which we have the year before we have a space station is a very, very large step. I think that we will walk up on the use of that rather gradually. We won't use it all at once. I think we'll have time to measure the demand that we create and the rapidity with which it builds up. We will have time to add to the capability that's necessary.

Our design is based upon the premise that we want to be able to grow it over time to 300 kilowatts. That's a reasonable upper target for a vehicle of this size. We have an upper target for the size of the crew in similar dimensions.

Mr. WALKER. What's that target?

Mr. CULBERTSON. Up to about 18 to 20 people by the addition of more habitats. But the basic structure will take care of that.

Now, I'm not going to try to make light of the problem that we're going to have in figuring out how to allocate the use of all these resources. It is going to be an extremely difficult thing because we will have demands not only from our international, we'll have competition and let's say pressing needs from our international participants and we'll have similar competition between our scientists in NASA itself and our commercial industries.

So we've got a very, very difficult formulation of how to allocate those resources, and then how to charge for them. We are working that problem today, but we're a long time, a long way from coming up with an equitable solution.

Mr. **Walker**. My colleagues have been very generous with my time here. Just one more issue I would raise with you that I hear feedback coming in is there's an understanding that you may have decided on a 10 psi environment. It is my understanding that again the commercial community is somewhat concerned about that because virtually no off-the-shelf technology could be utilized in a 10 psi environment. As I understand it, most off-the-shelf technology would be usable in about a 14 psi environment.

Has in fact that decision been made?

Mr. **Culbertson**. The decision has not been made. We spent a long time 2 months ago seeing if we were prepared to make that decision and concluded that we lacked the information to do it.

The decision on what the power will be, what the pressure level will be is being influenced by the impact that has on the pressure suit which will be involved, which will be used for EVA, and the extent to which a new suit will be required beyond the suit which is presently designed for the space shuttle. It will influence the ability of the private sector to—and ourselves, to use off-the-shelf equipment. It will influence the degree to which we can use results from research made on the ground. That is, there are certain kinds of research and which we have a vast body of data around at 14 psi—14.7 psi. There are those who would say that some of that base for comparison will be invalidated if we are trying to compare it with the research done in zero gravity at some lower pressure.

It also is influenced by the flammability considerations and the options we have in the use of materials. It is not a trivial question at all. It is also necessary for us to be compatible with the shuttle because the shuttle will be, at times that it is docked at the space station, we'll hope to have an open door between the shuttle and the station. So they'll have to be equalized in pressure.

That's one of the more complex decisions which we will make in this series of decisions that we have. I am fully aware of the concern of the private sector. And we have those same concerns. The off-the-shelf question is a deep question for me because I want to save what money I can in using off-the-shelf systems.

Mr. **Walker**. Thank you, Mr. Chairman.

Mr. **Nelson**. Mr. Slaughter.

Mr. **Slaughter**. Thank you, Mr. Chairman.

In connection with the schedule you have for putting up the space station, do you feel that NASA is able to make optimum use of the capabilities that it has and that we have in the country? If you had greater financial support, would you be able to do it sooner, or would it be wise to try to do it sooner?

Mr. **Culbertson**. Well, it's always easy to say that I'm on the most optimum schedule that's possible. I'm tempted to say that because I think it's pretty true, but I'm not going to say it.

I think that we're on about the right schedule. The concern I have is that you will not be able to fund me well enough to keep on that schedule. I think it would be imprudent to try to accelerate it very much if for no other reason than we are, you know, our scientists, our industrial concerns need to be working on a schedule which is related to ours, too. Because if we have a space station up that's—if we have it in orbit a year before the users are ready for it, then we will have made a bad mistake. And I think everybody is now keyed to the idea of having a space station operational in the early to mid-1990's.

It would be a mistake to draw it out any longer than that. It really would. I've compared the development span of the relationship between the overall program cost and the development span that we now project for the space station with about 25 other programs within NASA and found that we are in about the right relationship, cost to development time, in that programs which have been accelerated generally paid a penalty for that. And certainly programs that were drawn out paid a large penalty for it.

So I'm very comfortable with the schedule as we see it and think that it's close to the minimum cost.

Mr. **Nelson**. OK. Let me—oh, there's Mr. Monson. I'm sorry, I didn't see you.

Mr. **Monson**. Thank you, Mr. Chairman. And I apologize for coming in late, but sometimes we have other assignments, as you well know I'm sure, and I was assigned to be over on the floor today. So despite the fact there wasn't much going on I had to be there.

I would have liked to have heard all the testimony, and I appreciate the chance to talk to you for just a moment.

Mr. Moore, after hearing the publicity regarding the experience in the area and over the last part of last week there was quite a bit of speculation that it may be difficult to obtain insurance for all payloads in the future, not just those being flown by Ariane. Do you anticipate that being true? And if so, what do you think the alternatives might be?

Mr. **Moore**. Well, let me answer the latter. We are internally trying to assess what our alternatives are. Your former statement is certainly true. I think the insurance market is basically in a very large deficit situation right now with total losses over some 18 months I believe exceeding $500 million. I think we're in a very, very tough strait as far as insurance for future payloads are concerned.

We in my office in NASA are talking about what the alternatives are and have not come up with any good, bright ideas at this point in time, but we're certainly trying to see how we can strategize our way and work with our customers to come up with the best possible solution. But it is a very, very negative situation as far as flying on launch systems these days.

Mr. **Monson**. I realize the time has been short, but have you speculated on what the impacts of that might be on future payloads on the shuttle?

Mr. **Moore**. Well, I think that there are certain payloads that have signed up to fly in the next 2 to 3 years, for example, that have negotiated insurance contracts prior to this latest series of incidents. For people beyond that, you know, there are very few alternatives, I think. One, you may wind up paying extremely high insurance premiums to ride a particular launch vehicle, or maybe you go without insurance or some of the options if you've got some customers who want to use your communications satellite. I think those are the kind of issues that have to be debated and those are the kind of topics that we internally are looking at at this point in time.

Mr. Monson. And what impacts——

Mr. Nelson. Would the gentleman yield on that point?

Mr. Monson [continuing]. Certainly.

Mr. Nelson. Is there any indication that the insurance industry might insure upon the shuttle where they would not—as the launch vehicle, whereas they might not insure on the Ariane?

Mr. Moore. Mr. Chairman, I have not heard that particular possibility. I'm certainly sure that those kinds of options and those kind of ideas are certainly being debated within the insurance community, but we have not heard that as of this point in time.

Mr. Monson. What——

Mr. Moore. I think you mentioned at the outset of our conversation that you were going to set up a series of hearings with the insurance underwriters. I think that would be a very fruitful—yes, a very fruitful thing to do to get some of their firsthand impressions about how they have assessed this whole situation. Certainly we in the Shuttle Program, by the way, are trying to do everything that we can to help the insurance underwriters out as you have seen from the Palapa and Westar retrievals, and also our Syncom work, and so forth. I think that's one of the attributes this Nation ought to be very proud of and the investment it's made in the Shuttle Program where we have been able to use it for these kind of purposes in terms of helping ailing satellites in terms of getting back onto a fruitful lifetime.

Mr. Monson [continuing]. It appears from my viewpoint that the insurance industry in liability and casualty areas is having difficulty not only with space-related matters but just about everywhere in that industry, and that would seem to have some impact on the future ability to get insurance.

Assuming the worse, that they are unable to get insurance in the future, what budgetary impacts would that have on, on future shuttle flights?

Mr. Moore. Well, we've got a plan at this point in time that shows in the 1988–90 timeframe of three to four dedicated shuttle flights. You look at the communications satellite market, I think the satellite market now would show us we probably have around 15 satellites per year to be launched. If you talk about putting three satellites per shuttle launch, you're talking about four to five flights. Depends on, if you've got 15 communications satellites, you're talking about five dedicated shuttle flights. It depends upon the mix of those going on Ariane versus those that will fly on the shuttle. And it depends on whether or not the customer says I'm willing to take a risk and go with no insurance, whether or not he can get someone to buy insurance or give him insurance at very high premiums or other alternatives that he may have as his availability.

That's why I think the work that we are trying to internally assess the situation and the impact on the program is very crucially important as well as what this committee is planning to hold on October 30 when it brings in the underwriters. I think we're all deeply concerned about this. And I think you'd have substantial impacts on those communications satellite customers who are marginally in the business. I mean the business is not great, in my opinion. I don't think we're in a robust market right now as far as communications satellites are concerned. And those people who are on the borderline of thinking whether or not to take a venture of putting up a communications satellite that maybe they could sell transponders on, this may be certainly the driving force that would say they do not want to go into this business at this point in time.

So I don't think it's encouraging from that standpoint as well, plus it can cost us some flights on the shuttle.

Mr. Monson. Has the impact of this caused any, in the few days in any increase in interest by those that were planning to fly on the Ariane to renew interest in the shuttle?

Mr. Moore. No, I think it's, you know, we have some offers, two customers, out on the table at this point in time that I know we're competing with the Ariane on. But we have not seen any decisions made in the past few days. I really think it's probably a few weeks premature. I think this happened late last week, and here we are in the first couple days of this week. I think the longer term effects on this are yet to be seen. And I would suspect that—at least I would hope that a lot of the customers will begin to look favorably on the shuttle.

Mr. Monson. I realize that many of the considerations that we have in launching the shuttle relate to factors that they don't have to worry about, especially the potential loss of life, and I'm sure that that has a big effect on decisions to launch or to hold. The constant publicity that we hear that the shuttle isn't meeting its expectations concern me because I still think that there're some marvelous things happening there.

I assume you agree with that. But do you feel, can you reassure me that we still are on schedule in meeting what we expected to do in that regard?

Mr. Moore. Well, let me say I marveled at reading some of the press and articles around about the shuttle is a big albatross around the U.S. neck and so forth, and I really think it's been one of the greatest investments that the taxpayers in this country has made. I think the dividends that are being reaped from the Space Shuttle Program and what it will enable this country to do in the future are really just fabulous. And I believe the shuttle is meeting its objectives.

During this past fiscal year, for example, we doubled the flight rate from what we'd been able to achieve in the past 3 years. This program is a little over 4 years old. We've launched 20 flights to date. We've got essentially a flight a month scheduled for the next year, and I fully expect to meet those launches. We just had a successful test firing of our fourth Orbiter, Atlantis, at the Kennedy Space Center on September 12. That was a success. We believe we have four fine vehicles in the fleet. And I'm very optimistic about what I think the shuttle can do for this country.

I don't think we've set our goals too optimistic. I think they're achievable, and I think NASA's on a course to meet those objectives. I'm very proud of what the shuttle has done over the past decade and a half, since it started its development back in the 1972 timeframe. And I think it's done a lot of great things for this country and opened up a lot of endeavors that would not otherwise be possible today. I think we're seeing all kinds of things discussed about the potential of space.

We've got a space station now in our plans that I think the shuttle is a very integral part of. And there are a lot of things I think the shuttle has allowed this country to open up.

Mr. **Monson**. Thank you, Mr. Chairman.

Mr. **Culbertson**. Let me add something to what Jesse said, and it's just a personal observation, though. NASA is expected not to make mistakes. It is a legacy which we worked hard to get, but we're at a point now that anytime NASA hiccoughs a little bit it's a major disaster. And we're obviously not doing our job if we hiccough.

I'm delighted with the reputation that we've got; that we are not expected to make mistakes. But it is a kind of a—we carry that around on our shoulders every once in a while and it hurts occasionally.

Mr. **Nelson**. Well, as I said in my opening comments, what you all did with this satellite that was never intended to go through the tail of the Comet Giacobini-Zinner is just phenomenal. And my hat's off to you.

And I want to compliment the gentleman from Utah for your insightful questions. You're asking the right questions as we get ready for our hearing on October 30, and we'll have a little perspective of time. And I assume that if insurance is not available that there are certain commercial satellites that are going to have to be flown anyway.

Mr. **Moore**. I think that's right.

Mr. **Nelson**. And therefore, outside whose door are they going to line up?

Mr. **Moore**. Those are some of the very fundamental questions that we're talking about right now, Mr. Chairman.

Mr. **Nelson**. And I think that's going to be very interesting, to see how that shakes down.

Mr. **Moore**. I totally agree with you.

Mr. **Walker**. At that point maybe we can convince some people we need a fifth orbiter.

Mr. **Nelson**. That's right. That may well be an outcome. Who knows? Maybe all of our yapping will not have been in vain.

All right, let me sort of just tidy up everything here. In my opening comments I mentioned when I met with Dr. Sagdeev last week how clearly enthusiastic he was about your success with the comet encounter and how he's looking forward to receiving us in the Soviet Union. As we, since the subject of this is long-range planning, this hearing, is there anything more that any of you would like to share which is particularly timely as we get ready within a few weeks to take this delegation to the Soviet Union to talk about joint cooperation in space? Anything that you'd like to share with us?

Mr. **Moore**. I think I've covered essentially my plans. I plan to get together before that with members of your staff to talk some more about things, but it'll probably be more elaboration along some of the things that I've talked about here this afternoon, Mr. Chairman.

I'd also like to make a point if I might. Credit for the Giacobini-Zinner trajectory goes to a friend of mine, Dr. Bob Farquhar of the Goddard Space Flight Center. I've known him for an awfully long time and in my previous space science role at NASA. He's been very fundamental in defining unique trajectories. And Bob deserves a great deal of credit for targeting the ICEE spacecraft such that it could make this very fundamental encounter with the comet.

Mr. Culbertson. You saw that he was working on the trajectory which will bring that to the Earth in the year 2012 and rendezvous with my space station?

Mr. Moore. Yes.

Mr. Nelson. That's right.

Mr. Moore. That's very true.

Mr. Nelson. And then if you could rendezvous and capture that spacecraft, presumably you would be able to get so much data because you could get the particles of the comet that are on the outside of the spacecraft?

Mr. Moore. Sure.

Mr. Nelson. Even in the year 2012 that would give you a great deal of information?

Mr. Moore. Incredible. Yes, sir.

Dr. Colladay. There's another purpose for your space station, Phil.

Mr. Nelson. That's right. You've got another bullet item you can——

[Laughter.]

Mr. Nelson. Any comment that you might have as we're talking about, perhaps, an International Space Year in 1992. The 500th anniversary of Columbus discovering the new year—a new world, something like the 35th anniversary of Sputnik put up by the Soviets. It's a natural watershed point. It might be a topic of conversation for—certainly for us, but perhaps for the summit between the President and the Secretary-General. You got any comments about that?

Mr. Moore. No, today I personally don't have any comments. I will certainly give it some more thought, though. I think that's an interesting observation there about the 1992 timeframe. I will personally give it some additional thought. I don't have any comments today to add to it.

Mr. Culbertson. Yes, I think the whole agency sort of allowed ourselves to get caught. We have allowed ourselves a couple of times to get caught and we've passed up some opportunities. And it seems to me that this is an interesting opportunity for us to focus a number of things.

Mr. Nelson. Well, did we not have a great deal of international cooperation and advancement of aerospace planning and cooperation that came out of the International Geophysical Year? I said aerospace. I meant scientific cooperation that came out of the International Geophysical Year?

Mr. Moore. Um hum.

Mr. Nelson. And the thrust behind the legislation filed by Senator Matsunaga and myself is to build on that kind of experience.

Mr. Moore. Right.

Mr. Nelson. Any comments you want to share with us there?

Mr. MOORE. Well, I'd share one thing from a scientific point of view. I think Dr. Edelson will be testifying tomorrow, and I think a lot of his people have been involved in discussing ideas for the IGY. And we'll go back and ask him to be prepared to comment on that aspect at least from the scientific standpoint.

I know years ago we were looking at things that we could commemorate the 1992 timeframe, and you can think about some planetary machines that are likely to be flying during that period of time. Hopefully the Galileo spacecraft will be successfully orbiting Jupiter at that point in time, are some things that we can look at, and the Pioneers will be continuing to escape way beyond the boundaries of the solar system, and maybe some other planetary machines that will be functioning at that point in time which might be appropriate from a scientific point of view.

Mr. NELSON. Do any of you want to comment about how much we might look in the long-range planning to the reduction of costs of launching pounds into orbit?

Mr. MOORE. Well, I think I made a statement that I think we've got to set ourselves some objective of starting out at least trying to reduce the cost by an order of magnitude in terms of the cost per pound into orbit.

Mr. NELSON. Now what does that mean? Order of magnitude?

Mr. MOORE. Well, it means a factor of 10 reduction in the cost-per-pound now. For example, if you're talking about $2,000 per pound to orbit now, we would want to get it down to $200 per pound to orbit by setting ourselves that kind of a goal in order to make it much more efficient. And I think how well we're able to get toward that kind of a goal is going to decide the kind of systems that we want to implement in the future. Because I think that's going to be a big driver.

I think we have to look, Mr. Chairman, at what our mission needs statement say from the civilian agencies as well as the Department of Defense, and SDI included in the Department of Defense activities, as well as what Mr. Culbertson and the space station people are going to require as far as launch requirements are concerned.

Mr. CULBERTSON. I think a goal like that is—the most important thing that that can do is to lower that threshold of cost to the private sector.

Mr. MOORE. I think that's right, too, Phil.

Mr. CULBERTSON. And for those of us who think strongly that a significant part of the future of the Space Program will be wrapped around private investment, then I think it is the right goal and I think it will enable many things that are not being thought of today.

Mr. NELSON. And what you've done is, on a completely different subject, just summarize very neatly the argument that Mr. Walker and I have been making all along in trying to keep the shuttle pricing policy down at a low enough level in order to encourage private investment in space.

Mr. MOORE. Right.

Mr. CULBERTSON. Exactly.

Mr. **Nelson**. Because if the cost is too high, they won't go up there and invest in space no matter how promising the particular——

Mr. **Moore**. That's true.

Mr. **Nelson** [continuing]. Materials processing venture.

All right. Dr. Colladay, what technologies have you identified that you would like to expand for the shuttle in its so-called flight envelope?

Dr. **Colladay**. The technologies that we're focusing on really aren't so much for expanding the flight envelope of the shuttle, although we're talking about utilizing the shuttle for zero gravity experiments, using that as a test bed for control of large structure experiments. The vehicle itself, as I mentioned, we look at it as a research airplane. It's the only entry vehicle that we have, that this country has, that gives us an opportunity to collect upper atmosphere data at hypersonic entry speeds. And as a test bed not only for large structures, but telerobotic systems and environment definition, atomic oxygen problems and a whole host of considerations that have to be addressed if we want to design routinely for operating in space.

We're using the shuttle extensively. I think we have experiments on almost every flight that we can wedge our way in. And we've got the Columbia now fully instrumented with research instrumentation for entry data. That, by the way, is providing a very important source of information for the transatmospheric vehicle effort that we have.

Mr. **Nelson**. Mr. Culbertson, have you concluded now that the manned civil space station would meet what you want to do at the lowest cost as compared to alternative technologies where you would have an unmanned space station a long duration Orbiter? Have you drawn that conclusion?

Mr. **Culbertson**. Well, yes, I've drawn it in this sense. That we have focused in thinking about the space station and in talking to prospective users we have focused on the kinds of things that man will make possible in space since we have unmanned spacecraft in abundance and we can build more unmanned spacecraft. So we have tended to talk to people about what would you do with the presence of man that you could either not do if man was not there or would find it less effective to do if it was not there. And it is around that kind of user interest that we have focused our capabilities.

The question about a longer duration Orbiter is a slightly different question though. Well, the first question that I was trying to answer, did I think that we were focusing on the right kind of a station, a manned or unmanned station, and I don't think there's the slightest doubt about that. All of the things that I have talked about here were those things which were specific projects. I have not mentioned the fact that I believe that it is the presence of man in these systems which allows creative new ideas to take place during a mission. It is man's innovation that is important.

A scientific laboratory was described one time as a place to tinker. Well, you can't tinker with an unmanned system very well. And I think it is important that we provide a place to tinker.

The long duration Orbiter is a different kind of a thing it seems to me, and that is there are limitations that are clearly imposed by the space station. The space station will be in a single orbital inclination. We do not maneuver the space station and move it about very much. Where there are long manned missions to take place in either polar orbit or Sun-synchronous—well, we can't have them directly in Sun-synchronous orbit, but polar orbit or the higher inclinations launched out the Cape, I can see why a longer duration Orbiter capability may be advantageous for that sort of thing. It is not a competitor to the space station certainly in any sense.

We have looked at a long duration Orbiter up to maybe 15 days to determine its possible merit to assist in assembling the space station. And I haven't seen enough detail, we haven't got enough detail yet on the assembly of the space station to say whether or not the 7- to 10-day capability that we've gotten to now is going to be any limitation. I tend to feel that it is not, but I'm almost a year away from understanding that in the depth of detail that I would like to have it.

Mr. MOORE. One thing I would add, Phil, is that, as you know, we have a very interesting experiment coming up in the December flight on the shuttle. It's an experiment called Ease and Access and it looks at the productivity with respect to assembling structures in space. We'll build some tetrahedrons and some other structures and kind of measure the timing and so forth. Your people have been involved in it, and we will give you at least some measure, even though it will be very early measure of efficiency of what it will take in terms of assembling large structures in space. And this is one of the principal objectives of it, is to measure those kind of parameters and to plow that into things like the Space Station Program so that Phil can answer those kind of questions.

Mr. CULBERTSON. One of the direct measures to that first question, the manned or unmanned question, I think is as we have talked with users, and keep in mind I'm talking to users fundamentally about using a manned system, so that I'm not canvassing the entire world about what you want to do in space. It's fundamentally how will you use a manned system. But in talking to those and then measuring the resources that are required, clearly it is the crew time which at the moment is the most critical resource that we've got in the whole program.

Mr. MOORE. Right. That's right.

Mr. NELSON. OK. One final question. Mr. Culbertson, when do you think you can provide this committee with a realistic estimate of your operational costs on the station?

Mr. CULBERTSON. Well, I think you will ask me the same question when I testify in the spring, and I expect to have the answer.

Mr. NELSON. OK. Are there any other questions? Any other comments?

Do any of you have any questions for each other? [Laughter.]

Mr. MOORE. We have questions all the time for each other.

Mr. CULBERTSON. We even have questions of you.

Mr. NELSON. Do you have any questions for us?

Mr. CULBERTSON. No; I was jesting.

Mr. MOORE. No, sir, Mr. Chairman.

Mr. CULBERTSON. It's been a pleasure to be here this afternoon.

Mr. Moore. Yes; it has.

Dr. Colladay. It has.

Mr. Nelson. All right. Thank you. Good session.

The meeting's adjourned.

[Whereupon, at 3:48 p.m., the subcommittee was adjourned, to reconvene subject to the call of the Chair.]

NASA's LONG RANGE PLANS

THURSDAY, SEPTEMBER, 19, 1985

House of Representatives,
Committee on Science and Technology,
Subcommittee on Space Science and Applications,
Washington, DC.

The subcommittee met, pursuant to recess, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Bill Nelson (chairman of the subcommittee) presiding.

Mr. Nelson. Good morning. We are delighted to have Dr. Edelson, Mr. Aller, and Mr. Nysmith here to look at NASA's long-range plans.

Last Tuesday we heard from the Administrator, who shared his views about what's going to happen in the next decade. We talked to the Associate Administrators on the space station, space flight, and aeronautics and space technology. So we are starting to get a sense of the future space transportation infrastructure and what are the technologies that NASA is studying to support its technical needs.

Today we are going to look into areas where NASA has been a leader in science and technology and also as a self-sustaining, very robust organization. We're going to hear from Dr. Edelson, who will give us a view of the high-priority science missions.

Mr. Aller will tell us about the developments in the tracking and data systems which support all of NASA's missions.

Then we will look at the human element with Mr. Nysmith to see what's in store for NASA as an organization, particularly with a mind to wanting to continue NASA to have the extraordinary success that it's had in attracting the high-quality personnel that has been its benchmark over the past 25 years.

Now, these hearings are coming at a time when we're getting ready to go to the Soviet Union to discuss the potential of future cooperation in space with that nation. I would certainly entertain throughout this discussion today any suggestions for any of our discussions in Moscow and outside of Moscow.

I am aware of NASA's recent discussions with the Soviets regarding our support in the Halley's Comet mission. We are aware also in the hearings that we had last summer on the fact of how NASA acted in an unofficial capacity in order to have the two unofficial experiments that are now aboard the Soviet Vega spacecraft that is going to rendezvous with Halley's Comet.

I consider it a great tribute to our achievements in space tracking that we've been able to gain such an important goal in this international cooperative effort which the Soviets are looking to us for our tracking their particular international mission.

So it is with that frame of reference that we approach the hearing today. As I have requested of previous witnesses, I would appreciate it if you wouldn't read your testimony, but just talk to us. We have your testimony, and it will be inserted as part of the record.

Then what we will do is we will just get into a discussion with all three of you at the same time as we get into the questions.

We will insert Mr. Walker's statement in the record, and he will be joining us shortly.

So let's start with you, Dr. Edelson. Please proceed.

STATEMENT OF BURTON I. EDELSON, ASSOCIATE ADMINISTRATOR FOR OFFICE OF SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Edelson. Mr. Chairman, it's a pleasure to be here this morning to talk about planning in the Office of Space Science and Applications. We have an exciting, challenging program and many projects.

I have brought along some Vu-Graphs this morning to try to give you a feeling for our program trends that we are following, the strategy and plans that we have for each discipline area, and a list of major new flight starts that we hope to enter into over the next 5 years or so.

I will say a word about our use of the space shuttle and our plans for the use of the space station. I will at the end make some comments about the cooperative programs that we have with the Soviet Union, to get back to your interest on that point.

Our program extends literally to the edge of the universe. We have a very comprehensive, extensive program. We are, in our astrophysics and astronomy program, looking as far out in space as we possibly can with the most powerful instruments we can have. At the present time, that's a few billion light-years. Perhaps 2 to 3 billion light-years is what we can do with the finest instruments on the ground, such as Mount Palomar Observatory.

When we launch the Hubble space telescope in August of 1986, we hope to look out to what we consider to be the very edge of the universe, which may be 15 billion light-years.

Another way of saying that is we are going to be looking back in time 15 billion years because, as you know, with the concept of the "big bang" with the expanding universe, the thought is that the farther out you look in distance, the farther back you're looking in time. And so we can learn much about the origin of the universe by looking out to the very energetic objects which are out at the edge—shown there as well as we can depict them—distant galaxies and very unusual, bizarre objects such as quasars, pulsars, and black holes.

We are, of course, interested in intergalactic space and in understanding how our own galaxy is formed and the dynamics of it. We have, and have had, an extensive program in exploring our own solar system. We have explored, we've landed on the Moon. We've explored Mars and Venus quite thoroughly. We've had the Voyager mission to Jupiter and Saturn, now on to Uranus.

We are learning all about not only the planets but the primitive bodies, the comets and asteroids. You know we've had an extremely successful encounter this last week with the Comet Giacobini-Zinner, and we're looking forward to working with an international armada to encounter and observe Comet Halley's close approach.

Mr. **Nelson**. By the way—let me just interrupt you and tell you I shared this with Mr. Beggs the other day—but I just think that it is a real tribute to your professionalism in NASA that you all would take a spacecraft that had nothing to do with the comet and figure out how to slingshot it around the Moon and get it into this Giacobini-Zinner comet. That's just marvelous.

Now, that came primarily out of Goddard, did it not, the trajectories?

Mr. **Edelson**. Yes, sir; that was the genius of Dr. Robert Farquahar, who thought that up, conceived it, and sold the program to us and followed it to its successful—I almost said "conclusion."

Now he has ideas of keeping it going. It will come back to the vicinity of the Earth in the year 2012. He hopes to whip it around the Moon one more time and pick it up with either the shuttle or whatever vehicle they have operating in 25 years from now.

Mr. **Nelson**. OK. Then I would like very much some time to get that gentleman to come here to the committee and explain to us and share with us some of his excitement about how he figured all that out, so that he could get that to go rendezvous with that comet. That's just marvelous. Please.

Mr. **Edelson**. That will be easy to arrange, and we would be pleased to do it.

Coming in from our own solar system, we are interested, of course, in the relationship between the Sun and the Earth. We're interested in the Sun as a stellar laboratory. It's the only star that we can observe close up. We can observe its seismology and internal dynamics. We can measure its flux, both particulate and radiative flux of the Sun, and the interaction of the so-called solar wind with our own Earth's magnetosphere and its effect in causing the auroras and climate.

Coming down even farther to the planet on which we live, we have an extensive program in Earth science, trying to understand how our Earth operates as a system. The atmosphere, the solid Earth, and the oceans all interreact with the so-called biosphere, which is the living mass on Earth. And we have a major program in that.

Then, coupled with all is an applications program that uses space science, space technology, space systems, to perform a useful role and to provide benefits to life here on Earth in communications, in Earth observation, and in microgravity space application.

We have an extensive ongoing program. I will not ask you to read this, but with this Vu-Graph, which shows most of our applications program, and the next Vu-Graph, which shows our science program, you realize that we have a very extensive ongoing program.

All the projects listed there are approved. They are either in operation—that is to say, in orbit or on a deep-space trajectory, or under development. It includes projects such as the applications technology satellite, which is a communications satellite that has been in orbit and operating for 18 years now and on which NASA is spending, oh, something like at most $100,000 per year to keep the operation going, to the Hubble space telescope, which we will launch in August, a major development program on which we're spending $195 million this year.

So we've got many programs that are approved. Our plate is full already, you might say, of interesting and exciting programs, and we're busy carrying them out.

Now, the purpose here today is to start from this base and explain to you what our strategy and plans are in each of the discipline areas for the future.

These are the disciplines that we're involved with. You can see there are seven of them here, and we have developed or are developing a strategic plan for each discipline area. In order to develop those plans, we make use of the many—very many—advisory committees that we have. We reach out extensively into the science community. And because after all, they are in a way our customers, we're doing science not for NASA but for the scientific community of this country and, indeed, of the world.

So we have had a practice of reaching out and having a number of committees in individual disciplines work with us and advise us on our plans. So when I say, "This is our discipline, this is our plan," it's not something that I thought of or wrote down or my staff or the NASA centers did, it's something that we've done in conjunction with United States—and, in fact, in some cases, members of the international scientific community.

I am going to say a word about each of these in turn. In astrophysics, we have a program that, as I mentioned, reaches out. We've had the use of small explorer satellites, and larger spacecraft such as the HEAO x-ray satellite and others in the past.

We're now engaged in a program of looking at the distant universe across the full length of the electomagnetic spectrum. Our first major effort in this area is the Hubble space telescope. The second one, also approved, is the Gamma Ray Observatory.

We have in mind, and we are planning to go ahead with, the x-ray telescope, AXAF—advanced x-ray astrophysics facility—as soon as we can get that program lined up for a new start; and somewhat later, the infrared telescope, space infrared telescope.

This follows a strategy which came from the so-called Field committee, the Astronomy Survey Committee, led by Prof. George Field of Harvard, which studied under the auspices of the National Academy of Sciences and came up with a 10-year strategy for the United States in astronomy and astrophysics.

Of course, there's a program we've pursued jointly with the National Science Foundation. Essentially, we do the Space Program. The No. 1 priority on their list of new programs is AXAF. And, of course, they gave a strong endorsement also to CERTA.

We have a plan that is in a brochure, and we could lay it out, and it's a detailed strategy. We are working now with the Space Science Board and with our own advisory committee, the Space and Earth Science Advisory Committee—we call it SESAC—in this area—and I won't say it again, because it applies in all the areas—to develop, update the strategy, and to pursue it.

The next area that I would like to talk about is the solar system exploration. We have a program of providing at first reconnaissance and then more detailed measurement and then in-depth survey and measurement of various elements of the solar system, the planets, comets, and asteroids. Here we have the strategy and guidance set down by the Solar System Exploration Committee, SSEC, under the chairmanship of Prof. David Morrison of the University of Hawaii.

I won't go into it in detail, but we have followed that over the years, the Venus radar mapper, now approved, the Mars observer, now approved, were the top two recommendations of the SSEC.

The third recommendation, and the first of the class known as the Mariner Mark II, is CRAF, the comet rendezvous asteroid flyby, very high-priority, new-start mission for us. And that's to be followed by a Saturn orbiter and a lunar observer—lunar orbiter and Saturn orbiter combined with a Titan probe, a joint NASA-European mission which we're studying together, which will probably, hopefully, come about in the late 1990's.

Here's a program of great potential, great excitement, and one that has been a source of great pride of accomplishment for the United States and specifically for NASA.

Next, we are interested, as I mentioned, in the solar-terrestrial interface. We are interested in the internal dynamics, the solar flux, the solar wind, the interaction of the solar wind with the Earth's magnetosphere, the causation of the auroras and its effect upon Earth's climate.

An area of great potential interest and one in which we have lined up a program of exploration. It is, after all, the very first of the space sciences.

When Professor Van Allen of the University of Iowa put his geiger counter on the *Explorer I* in January of 1958, that was the start of—and discovered the Van Allen radiation belts—that was the first—he was the first space scientist, and that was the first space science experiment. And it was in this area of solar-terrestrial physics that he did his work, and we're trying to carry on with the tradition.

We have several projects in this area. One is the solar optical telescope, which is to ride on the space shuttle. Another is the space plasma laboratory, also a shuttle-attached flight, a spacelab flight.

And the new program which we have as a very high-priority new-start potential is ISTP, the International Solar-Terrestrial Physics Program, in which we hope to be engaged with ESA in Europe and ISAS in Japan.

Mr. Nelson. By the way, could solar flares have hurt our astronauts on the Moon?

Mr. Edelson. Yes.

Mr. Nelson. They could have?

Mr. Edelson. Yes, they could have. That was the basis of the book by——

Mr. Nelson. That's what I was thinking of, Michener's book, "Space."

Mr. Edelson. Yes; although it's not likely that they would arise as suddenly, and it would be quite a coincidence if it were timed that way. But, yes, that could have been very damaging if they were unprotected, let's say, on the moon, unprotected by the Earth's atmosphere on the moon at a time like that.

But solar activity goes up and down, and we would normally take protective action. Certainly, we would nowadays.

I didn't mention, but our solar-terrestrial strategy has been worked out by the Committee on Solar-Terrestrial Research and the Committee on Solar and Space Physics, two committees of the National Academy of Sciences and the Space Science Board.

I want to bring that home, that in every discipline area, we have a strategy and a plan worked out together with the scientific community.

In Earth science, we have—which is, in fact, a new area for NASA. We've always had an Earth Applications Program, but only 3 years ago, when we combined science and applications, when I first came to NASA, into one Office, did we have the opportunity to take on an Earth Science Program. And we have an extensive program in there.

We have chartered an Earth Systems Science Committee, composed of a number of Earth scientists, oceanographers, geologists, atmospheric scientists, meteorologists, and so on, as well as biologists, to study the science of the geosphere and biosphere together. And we're studying the Earth as a system.

We have a strategy in this area being worked out, and we have a series of space flights involving Earth observation, like the SIR A and SIR B radar flights that you've seen. The LANDSAT will contribute to that.

A high-priority new start, TOPEX, ocean topography satellite, will contribute to Earth science, and because it's so interactive, the ISTP will also connect solar-terrestrial physics to Earth science.

I failed to mention the upper atmosphere research satellite, which is an approved program, which is going to contribute very much to our Earth Science Program.

The Office of Space Science and Applications is also responsible for biomedical science. We have a Life Science Office, and that Office, unlike all of the other divisions over which I have responsibility, serves NASA-wide.

It is the only Office that has a life-science capability. So we provide the biomedical support for the Office of Space Flight, for the space shuttle. We're responsible for the health and the safety of the astronauts. We're responsible for the life-science input to the design of the life-support equipment on the shuttle. We do have the same role with respect to the design of the space station. I am not here to talk about those today. What I will talk about, just in a sentence or two, is the scope of our Science Program within life science.

We have a picture here, a range of things all the way from space biology, exobiology, to operational medicine. We are, at the basic level, looking into the origin of life in the universe, including the origin and evolution of life on Earth.

We are, as far as I have been able to ascertain, the only institution in the world—isn't it odd that the American space agency is doing this—but we are the only institution in the world that is mounting a comprehensive program aimed at understanding how life was formed in the universe and evolved here on Earth, to develop man and other species.

We have a space biology effort which is to understand the effect of gravity on biological processes, and we are performing flights on the shuttle, and we will look forward to the space station very much in this area because we are quite limited with the duration of shuttle for biological experiments. We need the long stay-time in orbit that the space station will provide in this area.

One other project in the life science area is our search for extraterrestrial intelligence, in which we are processing with very extensive, complex multichannel signal-processing systems, frequencies which might have intelligent modulation on the signal.

In a pure applications area, we have the Communications Satellite Development Program. That consists of several areas.

One is the advanced communications technology satellite, a program which is aimed simply at keeping and extending U.S. technological leadership in satellite communications, an area in which America has pioneered and in which our role has diminished somewhat in recent years as Japan and Europe have gone ahead.

We are now taking a step to leapfrog really a couple of generations in technology to develop the onboard processing technology, the satellite switching technology, the multibeam antenna technology that will be required in the future in communications satellites, which will put us clearly ahead of other nations.

In all the programs that I am talking about, the Communications Satellite Program, the so-called ACTS Program, is the only one in which we have not asked for nor invited, for obvious reasons, international cooperation. All of our science programs, we've invited international cooperation. The communications technology satellite, which is aimed at helping American technology, we have obviously discouraged international cooperation.

We also have plans for—we are planning for a Mobile Communications Satellite Program, which we are attempting to do together with industry as a cooperative development. We're going to provide the technological guidance, and we expect industry to step forward with the investment and to build and develop and operate the spacecraft. This is a program, the Mobile Communications Satellite Program, that we worked out jointly with Canada.

Mr. BROWN. Mr. Chairman, may I interrupt at this point?

Mr. NELSON. Certainly.

Mr. BROWN. Dr. Edelson, as you know, this committee has had a long-time interest in this national leadership in satellite communications, and we have seen the devotion to that, measured in terms of budgetary resources, tend to fluctuate a little bit, and a little bit of uncertainty really as to what our goal was. And you have just enunciated it, it seems to me, very clearly what our goal should be: to maintain national supremacy in this area of technology which this country pioneered in.

I would like to ask you if you feel that you have a clear mandate from the Congress and the administration to continue to maintain that role in cooperation with the U.S. industry to whatever research and development programs are necessary?

I don't mean that you have to usurp all the R&D in this area or anything, but do you feel that you have a mandate to continue to keep us in the role of global leadership—as I think we have such policy in the field of aeronautics, for example; the administration has reviewed that program thoroughly and has recommitted the Federal Government to maintain that role. And I am trying to ascertain if you feel we have a similar clear commitment in this field of satellite communications?

Mr. **Edelson**. In the formulation of the ACTS Program, Mr. Brown, in which you personally played such a strong supporting role and for which we're appreciative, I think that we have cut out for ourselves by the approval of that program a role in space applications and particularly in communications satellites.

As you are well aware, there were questions from all sides as to what is the Government's role, what is NASA's role in developing a technology which would benefit American industry? If it was so beneficial as everyone agreed that it was, why is it that industry shouldn't pay for it and do it itself?

The argument that was brought forth is:

> It's too expensive, it's too risky, and it's too diverse for a single industry or a consortium of industries to get together and do it, and yet it's necessary for the United States to do it.

We've taken kind of the sense of Congress and the legislative history there and used it for our charter to develop communications satellite technology and bring it to the test-and-demonstration stage.

So the answer to your question is, "Yes," and I feel that in getting the ACTS Program approved, we not only were able to put forward this very important program, but we were able to carve out a role and identify a mission for NASA in this area as well.

Mr. **Brown**. Well, it seems to me that the current work conference and the ones that are coming up in the future illustrate the international or global importance of this if for no other reason than fending off the other nations of the world that don't believe us when we say that we're maintaining the technology at such a rate that we are not going to preempt all the geostationary communications slots.

We've got to have a program that allows us to deal with these specialists from the rest of the world in a realistic way by maintaining the continued capability to meet all the global satellite communications needs in an effective way, and I think this program is the only way we're going to be able to do it.

Mr. **Edelson**. I agree with that, Mr. Brown. That's absolutely right.

It has been the U.S. position that the problems of shortage of the geostationary orbit arc and the radio frequency spectrum can be solved by technology. So it's incumbent upon us to develop that technology which will make that statement come true, and we are doing that.

Mr. **Nelson**. Are the economics of the ACTS Program severely threatened by virtue of the fact that fiber optics is now an economical system and will be considerably deployed over the next several years?

Mr. **Edelson**. There is lots of discussion on that. My answer to that question is, "No." Fiber optic cable is a cable. It's a very efficient and a very wide bandwidth cable, but it's still a cable and it connects point A to point B.

The advantages of satellite communications are that it provides multiarea coverage and complete flexibility in going from A to any number of points, one point to multiple points and from multiple points to a single point, and it can perform broadcasting to mobile stations.

Now, in the single area of trunking—that is to say, if you wanted to send 10,000 telephone circuits from the east coast of the United States to Europe in that area, fiber optic cable will be a much more efficient cable than the copper cables that are now across the Atlantic and therefore will strike a different balance between satellites and cables than now exists.

So in the one area of trunking, yes, they are competitive, and where a more efficient cable will help, that would strike the edge there. But also, fiber optic cables have great use in local area networks and other local systems which tend to provide wideband communications, which is the market for satellite communications. So I would think they're complimentary.

Before I leave the communications program, I don't want to fail to mention our Search-and-Rescue Satellite Program, which is a highly successful program and which has actually saved more than 400 lives at sea and in mountainous areas from shipwrecks and plane crashes. We have documented cases. We have a long list of these that we hand out.

We have a nice brochure on it which tells about the accomplishments of the search-and-rescue system, which is an international system in which we are cooperating with the Soviet Union, with France, and with Canada. It is a low-cost system, and has been beneficial in the most obvious of all ways: by saving human lives.

Now, another new field—and I have really mentioned two new fields now, Earth science and microgravity science—are fields that we are bringing along in NASA and which we are developing a strategy is being done in microgravity science and applications.

We are doing basic science in microgravity. We have a program called PCES, physics and chemistry experiments in space, in which we are looking at basic physical and chemical processes in the microgravity environment.

As you know, for the last several hundred years we have done experiments in physics and chemistry in the laboratory and we've varied pressure and temperature. Dr. Hoyle and Dr. Charles created laws which we all learn about in high school and which we follow which tell about behavior when you vary pressure and temperature. But the single ingredient of gravity has stayed constant all that time. It's a very important force and function, and we now for the first time have a laboratory in which we can vary gravity and get a basic understanding of gravity.

That is half our program, microgravity science. The other is microgravity applications. And I can't easily put things in one category or the other, so we run them together.

The other major thrust is to develop useful benefit by performing microgravity processes in space, and we generally refer to that, and indeed the budget line item is called materials processing in space.

We are interested in those processes—on the left. You know that the process of transfer through convection is a gravity-driven process and what happens in fluid flow processes like electrophoresis in the absence of gravity and therefore convection current and sedimentation and buoyancy and so on.

We've divided our program into those disciplines, and we feel that there are practical applications in all of those which we are experimenting on and working with.

In this area, we're working hand in hand with Ike Gillam, who is Assistant Administrator for Commercial Processes, in trying to develop the science and perform the necessary experiments which will help him in his effort to commercialize some of these processes. So he and I and our group are working very close together in this area.

Now I have gone through the seven disciplines, and I am going to give you three Vu-Graphs which kind of sum up what we're doing in three areas.

One is our new flight start. I am going to say a word about our Shuttle Program and a word about our Space Station Program after this.

We really do, Mr. Chairman, have a planning process. It's often been said that planning and budgeting are the same thing, and perhaps it is. But not in the Office of Space Science and Applications.

We have a year-long planning process in which we develop a strategic plan and then work out a discipline plan for each area, culminating usually about the first of May in which we have a management council, planning council meeting in which we get together and we argue and we vote, if necessary, on our priorities.

There are many arguments and many discussions, and we take all the ingredients of all the advisory committees and everybody's prejudices and thoughts and put them together and come up with a plan. An important element of the plan is a prioritized list of new starts, and there before you is the prioritized list of new starts that we came up with in May of 1985.

Starting from the top and going on down are those programs that we feel are the most important of the 30 that we started with, that are lined up in priority order for how we are going to try to get approval of those.

Well, then, having a plan, the budgeting process is, you know, obviously an attempt to squeeze as much of the plan as you possibly can into next year's budget. It is of enormous help to go into the budgeting process with a plan.

I won't go into them into detail. I think I have mentioned them all in passing.

Our No. 1 new start, which we hope to get soon—parenthetically, I am not allowed to say anything about our fiscal year 1987 budget, which is under consideration between NASA and OMB at the present time. In spite of what you've read in Aviation Week and so on, I shall not say anything about it.

We have made a point of putting TOPE at the top of our list. Here is the only program that we've ever had that has been put No. 1 in priority by both the Applications Advisory Committee and the Science Advisory Committee.

Our second program is ISTP, and I won't read it. You can see it there.

The top four are ready to go. They're all super programs. They've gone all through the NASA new-start procedures—I am sorry, the first three have, the AXAF still has a way to go there. They are technologically ready to go.

They are very strongly supported by the appropriate segment of the scientific community, and we've honed them to such a fine edge of perfection and brochuremanship and graphic presentations and the real technological readiness of the programs to go through that it's almost hard to resist the pressure of them nowadays.

It's a wonderful experience to have programs at that state of importance and readiness, and the hard job for me and for Mr. Beggs is to try to decide which of those to push forward.

OK. So that's our list of new starts, and I could go through and explain each one as to what it is. I won't.

I will point out that those that are marked with an asterisk, the Earth observation system and the geostationary platform, are directly connected with the space station. EOS is on the polar platform of the proof space stations. The geostationary platform is a high-priority plan for the space station after IOC. You might say it's outside of the $8 billion envelope.

OK. What I showed there was the independent major new-start flight programs. I just listed here to bring to your attention the fact that we do have a series of spacelabs and other major experiments that we've planned and that we're carrying forward on the space shuttle.

I am sorry about all the initials there. Actually, this is a mixed list. This is all the shuttle flights.

Mr. NELSON. What is Astro I?

Mr. EDELSON. Astro I, sometimes called Astro Halley, is a set of telescopes that will fly on the shuttle in March 1986 to observe Comet Halley at the time of the encounter.

Mr. NELSON. I see. And MSL II?

Mr. EDELSON. That's materials science laboratory.

Mr. NELSON. I see.

Mr. EDELSON. And that's a set of microgravity experiments that we fly as frequently as we can on the shuttle. EOM is Earth observation mission.

Spartans are a successor to the Rocket Program. They are small spacecraft that we put overboard for a few hours or a few days from the shuttle to collect scientific data, then bring them back.

Mr. NELSON. Now, does the long-duration facility, does that come under your bailiwick? LDEF?

Mr. EDELSON. No; it does not. The way we're organized in NASA, my Office provides the mission management of it. It is a program of OAST, the Office of Aeronautics and Space Technology. And it's up there.

Mr. NELSON. I know.

Mr. EDELSON. When and if we get it back, then we've worked out a plan so that the LDEF hardware will be turned over to my Office, and we will use it for a program in detection of heavy nuclear particles, as a particle catcher.

The last Vu-Graph, I want to emphasize the fact that we're heavily involved in the Space Station Program. We support it strongly. We've worked out a plan to devote a significant part of our budget to use of the space station. We have published a plan for science and applications on the space station at IOC.

We are working on other documents as to how we will use the space station for science and applications after IOC. We're working on engineering documents and others.

We have five missions that we perform on the space station, and we've listed them in priority order, starting with servicing and repair. And we hope, as I mentioned before, to get a sixth mission, which is geostationary platform, after IOC.

That's the end of my presentation, Mr. Chairman. I would be pleased to answer questions or to join with my colleagues.

[The prepared statement of Mr. Edelson follows:]

NASA
National Aeronautics and
Space Administration

LONG RANGE PLANNING

SPACE SCIENCE AND APPLICATIONS PROGRAM

B. I. EDELSON
Associate Administrator for
Space Science and Applications
September 19, 1985

OSSA

PRESENTATION OUTLINE

- GOALS AND OBJECTIVES
- ORGANIZATION, BUDGET, PROGRAMS
- STRATEGY AND PLANNING BY DISCIPLINE
- POTENTIAL NEW MISSIONS
- SHUTTLE PAYLOADS
- SPACE STATION

OSSA

NASA GOALS

- PROVIDE FOR OUR WORK FORCE A CREATIVE ENVIRONMENT AND THE BEST OF FACILITIES, SUPPORT SERVICES, AND MANAGEMENT SUPPORT SO THEY CAN PERFORM WITH EXCELLENCE NASA'S RESEARCH, DEVELOPMENT, MISSION, AND OPERATIONAL RESPONSIBILITIES. PROVIDE FOR THE DEVELOPMENT OF EMPLOYEES SO AS TO ENHANCE AND SUSTAIN AN INTEGRATED WORK FORCE OF HIGHEST QUALITY AT NASA.
- MAKE THE SPACE TRANSPORTATION SYSTEM FULLY OPERATIONAL AND COST EFFECTIVE IN PROVIDING ROUTINE ACCESS TO SPACE FOR DOMESTIC AND FOREIGN, COMMERCIAL, AND GOVERNMENTAL USERS.
- DEVELOP WITHIN A DECADE A PERMANENTLY MANNED SPACE STATION
- CONDUCT AN EFFECTIVE AND PRODUCTIVE AERONAUTICS RESEARCH AND TECHNOLOGY PROGRAM WHICH CONTRIBUTES MATERIALLY TO THE ENDURING PREEMINENCE OF U.S. CIVIL AND MILITARY AVIATION.
- ➤ CONDUCT AN EFFECTIVE AND PRODUCTIVE SPACE AND EARTH SCIENCES PROGRAM WHICH EXPANDS HUMAN KNOWLEDGE OF THE EARTH, ITS ENVIRONMENT, THE SOLAR SYSTEM, AND THE UNIVERSE.
- ➤ CONDUCT EFFECTIVE AND PRODUCTIVE SPACE APPLICATIONS AND TECHNOLOGY PROGRAMS WHICH CONTRIBUTE MATERIALLY TOWARD U.S. LEADERSHIP AND SECURITY.
- EXPAND OPPORTUNITIES FOR U.S. PRIVATE SECTOR INVESTMENT AND INVOLVEMENT IN CIVIL SPACE AND SPACE-RELATED ACTIVITIES.
- ESTABLISH NASA AS A LEADER IN THE DEVELOPMENT AND APPLICATION OF ADVANCED TECHNOLOGY AND MANAGEMENT PRACTICES WHICH CONTRIBUTE TO SIGNIFICANT INCREASES IN BOTH AGENCY AND NATIONAL PRODUCTIVITY.

OSSA

OFFICE OF SPACE SCIENCE AND APPLICATIONS SPECIAL OBJECTIVES

PROGRAM PLANNING:
- LONG TERM STRATEGIES FOR EACH MAJOR AREA
- FIVE YEAR PLAN AND IMPLEMENTATION SCHEDULE FOR EACH AREA
- FY 1987 BUDGET PROPOSALS FOR FLIGHT PROJECTS AND RESEARCH BASE
- EXPLORERS AND PLANETARY OBSERVERS
- SHUTTLE PAYLOADS AND SPACE STATION UTILIZATION
- GLOBAL HABITABILITY PROGRAM
- BIOMEDICAL RESEARCH

MANAGEMENT:
- FLIGHT PROJECTS AND RESEARCH BASE
- INSTITUTIONAL MANAGEMENT – GSFC AND JPL
- HIRE THE BEST PEOPLE; PURSUE AGENCY EQUAL OPPORTUNITY GOALS; FOLLOW-UP ON FRESH-OUT INITIATIVE
- SUPPORT THE AGENCY'S PRODUCTIVITY AND COMMERCIALIZATION OBJECTIVES

OSSA

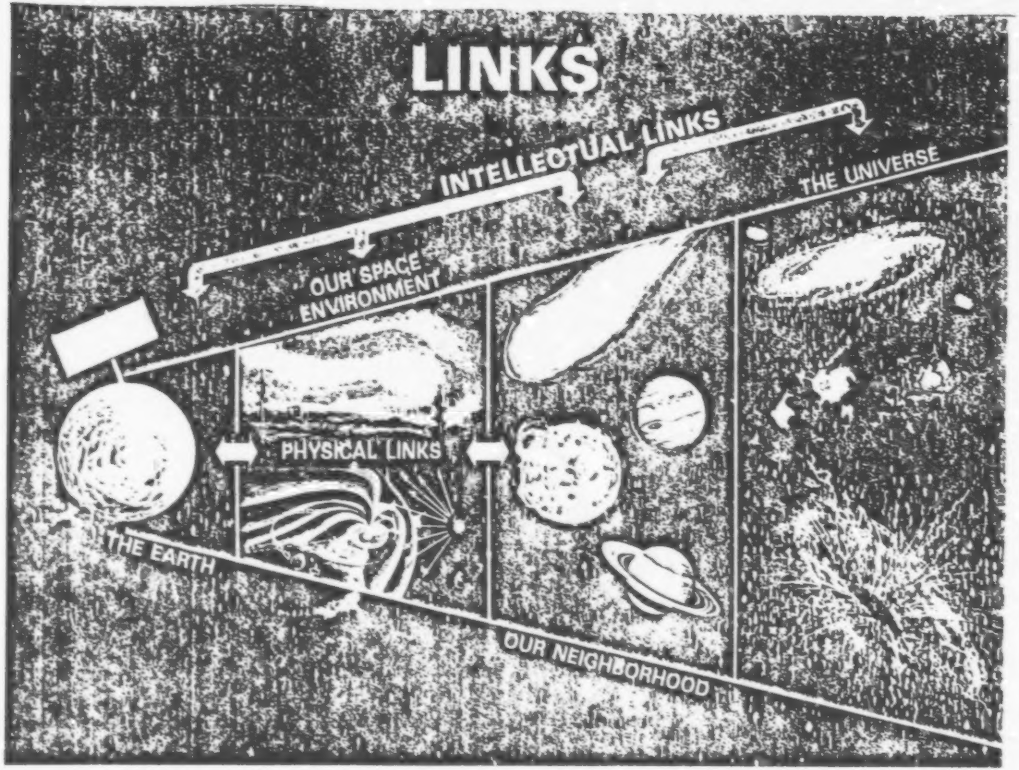
OFFICE OF SPACE SCIENCE AND APPLICATIONS BASELINE PROGRAM

MISSION	IN OPERATION	IN DEVELOPMENT
ASTROPHYSICS		
SOLAR MAXIMUM MISSION (SMM)	✓	
INTERNATIONAL ULTRAVIOLET EXPLORER (IUE)	✓	
HUBBLE SPACE TELESCOPE (HST)		✓
GAMMA RAY OBSERVATORY (GRO)		✓
COSMIC BACKGROUND EXPLORER (COBE)		✓
EXTREME ULTRAVIOLET EXPLORER (EUVE)		✓
SOLAR SYSTEM EXPLORATION		
PIONEERS 6-11	✓	
PIONEER VENUS	✓	
VOYAGER 1 AND 2	✓	
INTERNATIONAL COMETARY EXPLORER (ICE)	✓	
GALILEO		✓
ULYSSES		✓
VENUS RADAR MAPPER (VRM)		✓
MARS OBSERVER		✓

OSSA

OFFICE OF SPACE SCIENCE AND APPLICATIONS BASELINE PROGRAM

MISSION	IN OPERATION	IN DEVELOPMENT
EARTH SCIENCE AND APPLICATIONS		
LANDSAT-4 & 5	✓	
INTERNATIONAL SUN-EARTH EXPLORERS 1 & 2 (ISEE)	✓	
NIMBUS-7	✓	
DYNAMICS EXPLORER 1 (DE)	✓	
INTERPLANETARY MONITORING PLATFORM 8 (IMP)	✓	
SOLAR MESOSPHERIC EXPLORER (SME)	✓	
EARTH RADIATION BUDGET EXPERIMENT (ERBE)	✓	
ACTIVE MAGNETOSPHERE PARTICLE TRACER EXPLORER (AMPTE)	✓	
UPPER ATMOSPHERE RESEARCH SATELLITE (UARS)		✓
SCATTEROMETER		✓
COMMUNICATIONS		
APPLICATIONS TECHNOLOGY SATELLITES (ATS)	✓	
ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)		✓
SHUTTLE PAYLOADS		
EOM 1/2, SLS 1 & 2, ASTRO 1 & 2, ETC.		✓
SOLAR OPTICAL TELESCOPE (SOT)		✓


LINKS
INTELLECTUAL LINKS
THE UNIVERSE
OUR SPACE ENVIRONMENT
PHYSICAL LINKS
THE EARTH
OUR NEIGHBORHOOD

OSSA

STRATEGY AND PLANNING BY DISCIPLINE

- ASTROPHYSICS
- SOLAR SYSTEM EXPLORATION
- SOLAR TERRESTRIAL SCIENCE
- EARTH SCIENCE AND APPLICATIONS
- LIFE SCIENCES
- MICROGRAVITY SCIENCE AND APPLICATIONS
- COMMUNICATIONS

OSSA

PROGRAM STRATEGIES

SCIENCE

CHALLENGES:

- TRACE ORIGIN AND EVOLUTION OF THE UNIVERSE
- TRACE ORIGIN AND EVOLUTION OF THE SOLAR SYSTEM
- UNDERSTAND DEVELOPMENT OF LIFE IN THE UNIVERSE
- OBSERVE EARTH AND ITS ENVIRONMENT

APPLICATIONS

CHALLENGES:

- DETERMINE MICROGRAVITY EFFECTS ON MATTER AND MATERIALS PROCESSING
- DEVELOP, TEST AND DEMONSTRATE ADVANCED COMMUNICATIONS TECHNOLOGY AND SYSTEMS
- DEVELOP, TEST AND DEMONSTRATE ADVANCED REMOTE SENSING TECHNOLOGY AND SYSTEMS
- DEVELOP ADVANCED DATA PROCESSING, STORAGE, PRODUCTION AND DISTRIBUTION CAPABILITIES

OSSA

PROGRAM STRATEGIES

SCIENCE

MEANS:

- MAJOR FLIGHT MISSIONS, EXPLORERS AND PLANETARY OBSERVERS
- BALLOONS, ROCKETS, SATELLITES, SHUTTLE PAYLOADS AND EXPERIMENTS, SATELLITES AND SPACE STATION (FUTURE)
- SUPPORTING RESEARCH AND TECHNOLOGY DEVELOPMENT
- INTERNATIONAL COOPERATION

APPLICATIONS

MEANS:

- FLIGHT TESTS AND EXPERIMENTS
- APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT
- JOINT VENTURES WITH INDUSTRY

ASTROPHYSICS

CHALLENGE: UNDERSTAND ORIGIN, EVOLUTION, AND STRUCTURE OF THE UNIVERSE
UNDERSTAND LAWS OF PHYSICS THAT GOVERN IT

RESPONSE: NAS ASTRONOMY SURVEY COMMITTEE (FIELD COMMITTEE)

MAJOR OBSERVATORIES

- HUBBLE SPACE TELESCOPE (HST)
- ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)
- LARGE DEPLOYABLE REFLECTOR (LDR) IN THE IR AND SUB-MM

MODERATE MISSIONS

- GAMMA RAY OBSERVATORY (GRO)
- SPACE INFRARED TELESCOPE FACILITY (SIRTF)
- GRAVITY PROBE-B (GP-B)

EXPLORER MISSIONS

- COSMIC BACKGROUND EXPLORER (COBE)
- EXTREME ULTRAVIOLET EXPLORER (EUVE)
- X-RAY TIMING EXPLORER (XTE)
- FAR ULTRAVIOLET SPECTROSCOPY EXPLORER (FUSE)

SPACELAB AND SPACE STATION FACILITIES

- SOLAR OPTICAL TELESCOPE (SOT)
- PINHOLE/OCCULTER FACILITY (P/OF)
- ADVANCED SOLAR OBSERVATORY (ASO)
- ASTRO-1,2,3
- SUNLAB
- SHUTTLE IMAGING RADAR
- "DARK SKY"

STRENGTHEN RESEARCH BASE

SOLAR SYSTEM EXPLORATION

CHALLENGE: UNDERSTAND ORIGIN AND EVOLUTION OF THE SOLAR SYSTEM

RESPONSE: SOLAR SYSTEM EXPLORATION COMMITTEE REPORT

COMPLETE ONGOING PROJECTS
- PIONEERS
- VOYAGER - URANUS AND NEPTUNE ENCOUNTERS
- GALILEO
- VENUS RADAR MAPPER (VRM)
- MARS OBSERVER

MAINTAIN HIGH PRIORITY MISSIONS OF MODEST COST
- COMET RENDEZVOUS/ASTEROID FLYBY (CRAF)
- SATURN ORBITER/TITAN PROBE ("CASSINI")
- MAIN BELT ASTEROID RENDEZVOUS MISSION (MBAR)

IMPLEMENT PLANETARY OBSERVER PROGRAM
- LUNAR GEOSCIENCE OBSERVER (LGO)
- NEAR-EARTH ASTEROID RENDEZVOUS MISSION (NEAR)
- COMET COMA SAMPLE RETURN MISSION

INITIATE LARGER-SCALE TECHNOLOGICALLY DRIVING AUGMENTED MISSIONS
- MARS SAMPLE RETURN (MSR)
- COMET NUCLEUS SAMPLE RETURN (CNSR)

UTILIZE SPACE STATION FOR SOLAR SYSTEM OBSERVATIONS/RESEARCH
- PLANETARY DETECTION TELESCOPE
- COSMIC DUST COLLECTORS

SUSTAIN RESEARCH BASE

EARTH SCIENCE

CHALLENGE: UNDERSTAND INTEGRATED FUNCTIONING OF PLANET EARTH

RESPONSE. COMPLETE EARTH SYSTEM SCIENCE STUDY

COMPLETE ONGOING PROJECTS
- o EARTH RADIATION BUDGET EXPERIMENT (ERBE)
- o UPPER ATMOSPHERE RESEARCH SATELLITE (UARS)

PLAN FUTURE MISSIONS
- o OCEAN TOPOGRAPHY EXPERIMENT (TOPEX)
- o INTERNATIONAL SOLAR TERRESTRIAL PHYSICS (ISTP) PROGRAM
- o GEOPOTENTIAL RESEARCH MISSION (GRM)
- o EARTH OBSERVING SYSTEM (EOS)

STUDY PROCESSES/CALIBRATE OBSERVATIONS
- o EXTENSIVE NON-ORBITAL MEASUREMENTS
- o SPACE PLASMA LAB (SPACELAB-2, SPL-1)
- o SHUTTLE INSTRUMENTS (EOM, ATMOS, SIR, SISEX)

IMPLEMENT GLOBAL HABITABILITY PROGRAM

PLAN FOR UTILIZATION OF SPACE STATION

SUSTAIN AND UNIFY RESEARCH BASE

LIFE SCIENCE

CHALLENGE: UNDERSTAND THE DEVELOPMENT OF LIFE IN THE UNIVERSE AND ADVANCE HUMAN PRODUCTIVITY IN SPACE

RESPONSE: DEVELOP STRATEGY
TRACE ORIGIN, EVOLUTION AND DISTRIBUTION OF LIFE IN UNIVERSE

- PREBIOTIC CHEMISTRY AND GEOLOGIC RECORD
- SOLAR SYSTEM EXPLORATION FLIGHTS (E.G., GALILEO, MGCO, CRAF)
- SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

DEVELOP CAPABILITY FOR LONG DURATION SPACE FLIGHT

- PHYSIOLOGICAL ADAPTATION TO WEIGHTLESSNESS AND READAPTATION TO EARTH ENVIRONMENT
- SHUTTLE EXPERIMENTS (E.G., MIDDECK, SPACELAB)
- ROLE OF GRAVITY IN DEVELOPMENT (EGG TO ADULT)
- GRAVITY RECEPTOR MECHANISMS (ANIMAL AND PLANT)
- SHUTTLE EXPERIMENTS
- SPACE STATION PLAN AND STUDIES

PERFORM INTERDISCIPLINARY RESEARCH TO UNDERSTAND THE EFFECTS OF LIFE ON THE BIOSPHERE

- GLOBAL BIOLOGY PROGRAM PLAN
- ROLE OF BIOTA AS MODULATORS OF BIOGEOCHEMICAL CYCLES
- CAPITALIZE ON REMOTE SENSING (E.G., AVHRR, LANDSAT)
- DYNAMIC MODELLING OF GLOBAL BIOLOGICAL PROCESSES

MICROGRAVITY SCIENCE AND APPLICATIONS

CHALLENGE: DEVELOP AND UNDERSTAND MICROGRAVITY EFFECTS ON MATTER, MATERIALS & PROCESSES

RESPONSE:

- DEVELOP AND EXPAND UNDERSTANDING OF THE BEHAVIOR OF MATERIALS AND FLUIDS IN MICROGRAVITY ENVIRONMENT

- IDENTIFY EMERGING SPACE PROCESSING TECHNOLOGIES THAT CAN RESULT IN COMMERICAL APPLICATION

    - FOSTER SCIENTIFIC RESEARCH TO BUILD A BROAD KNOWLEDGE BASE OF PROCESSING IN A SPACE ENVIRONMENT: METALS AND ALLOYS; GLASSES AND CERAMICS; BIOPROCESSING; ELECTRONIC MATERIALS; COMBUSTION; FLUID DYNAMICS

    - CREATE AWARENESS OF POSSIBLE COMMERCIAL OPPORTUNITIES TO INDUSTRY

    - ENCOURAGE PRIVATE SECTOR PARTICIPATION IN MICROGRAVITY EXPERIMENTATION THROUGH UTILIZATION OF JOINT ENDEAVOR AGREEMENTS, TECHNICAL EXCHANGE AGREEMENTS, AND INDUSTRIAL GUEST INVESTIGATOR AGREEMENTS

- UTILIZE SPACE SHUTTLE OR SMALLER-SCALE FLIGHT EXPERIMENTS FOR TECHNIQUE DEMONSTRATIONS

- PLAN FOR UTILIZATION OF SPACE STATION FOR LARGE-SCALE SPACE RESEARCH & PROCESSING LABORATORY

SATELLITE COMMUNICATIONS

CHALLENGE: DEVELOP AND TEST ADVANCED ENABLING SPACE COMMUNICATIONS TECHNOLOGY TO CONTINUE U.S. PREEMINENCE IN SATELLITE COMMUNICATIONS

RESPONSE: WORK WITH OAST TO DEVELOP FUNDAMENTAL COMPONENT AND DEVICE TECHNOLOGY FOR GENERIC COMMUNICATION APPLICATIONS

- POWER AMPLIFIERS
- MATRIX SWITCHES
- BASEBAND SIGNAL SWITCHING AND PROCESSING
- OPTICAL SIGNAL TRANSMITTERS/MODULATORS
- LOW NOISE AMPLIFIERS
- MONOLITHIC MICROWAVE/MILLIMETER WAVE CIRCUITS

CARRY OUT REQUIRED PROOF OF FEASIBILITY FLIGHT EXPERIMENTS USING FREE-FLYERS, SHUTTLE, AND SPACE STATION, ON SELECTED HIGH RISK SYSTEMS AND SUB-SYSTEMS

- MOBILE SATELLITE COMMUNICATIONS
- GEOSTATIONARY PLATFORMS
- DEMAND ASSIGNMENT NETWORKS
- LASER COMMUNICATIONS

EXECUTE SELECTED FOCUSED COMMUNICATIONS SYSTEM DEVELOPMENT IN KEY AREAS IN SUPPORT OF THE SPACE STATION, HIGH DATA RATE COMMUNICATIONS BY SCIENTIFIC USERS, AND ADVANCED SATCOM SYSTEMS

- MULTIPLE BEAM/SCAN BEAM FEED ARRAYS
- LARGE DEPLOYABLE REFLECTORS
- RF & LASER INTERSATELLITE LINKS
- ON ORBIT SPACECRAFT ASSEMBLY AND TEST
- FAR FIELD ANTENNA RANGE IN SPACE
- SPACE STATION COMPLEX ADVANCED (GROWTH) COMM NETWORK

REMOTE SENSING

CHALLENGE: CONTINUE U.S. LEADERSHIP IN INSTRUMENTATION AND DATA ANALYSIS FOR OPERATIONAL REMOTE SENSING

RESPONSE:

o CONTINUE ADVANCED RESEARCH IN DATA INTERPRETATION AND UTILIZATION STUDIES (WEATHER PREDICTION MODELS, SEVERE STORM PREDICTIONS, CLIMATE MODELS, ETC.)

o WORK WITH NOAA TO DEFINE INSTRUMENTATION OPPORTUNITIES AND NEEDS (MLA, IMAGING SPECTROMETER, IMAGING RADAR, SCATTEROMETER, ETC.)

o IDENTIFY AREAS OF MUTUAL BENEFIT TO LONG-TERM SCIENTIFIC UNDERSTANDING AS WELL AS NEAR-TERM ECONOMIC UTILITY (SCATTEROMETER, OCEAN COLOR IMAGER, ETC.)

o REVISE NASA/NOAA BASIC AGREEMENT TO ASSURE DELINEATION OF APPROPRIATE RESPONSIBILITIES AND ROLES

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OSSA

OFFICE OF SPACE SCIENCE AND APPLICATIONS
POTENTIAL MISSIONS

- NEAR TERM (FY 87-88)
  - OCEAN TOPOGRAPHY EXPERIMENT (TOPEX)
  - INTERNATIONAL SOLAR TERRESTRIAL PHYSICS PROGRAM (ISTP)
  - COMET RENDEZVOUS/ASTEROID FLY-BY (CRAF)
  - ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)

- LONGER TERM (FY 88 OR LATER)
  - GEOPOTENTIAL RESEARCH MISSION (GRM)
  - LUNAR GEOCHEMICAL ORBITER (LGO) +
  - SPACE INFRARED TELESCOPE FACILITY (SIRTF)
  - GRAVITY PROBE-B SCIENCE MISSION
  - EARTH OBSERVING SYSTEM (EOS)*
  - GEOSTATIONARY PLATFORM*
  - SATURN ORBITER/TITAN PROBE (SOTP)

* SPACE STATION PAYLOADS

+ PLANETARY OBSERVER

OCEAN TOPOGRAPHY EXPERIMENT (TOPEX)

MAJOR DISCIPLINE: OCEANOGRAPHY

MISSION OBJECTIVES: IMPROVED UNDERSTANDING OF THE GENERAL CIRCULATION OF THE GLOBAL OCEANS

RATIONALE:

- o GLOBAL OBSERVATIONS OF THE OCEANS ARE NOT POSSIBLE USING TRADITIONAL TECHNIQUES
- o SEASAT DEMONSTRATED THE FEASIBILTY OF MAKING CRITICAL OCEAN MEASUREMENTS FROM SPACE
- o MEASUREMENTS IN SEA SURFACE TOPOGRAPHY, CAN BE USED TO INFER THE MOVEMENT OF WATER THROUGH THE OCEANS
- o SUCH KNOWLEDGE WOULD PERMIT THE STUDY OF:
  - -- THE INTERACTION OF THE ATMOSPHERE WITH THE OCEANS
  - -- HEAT REDISTRIBUTION BY THE OCEANS
  - -- THE ROLE OF THE OCEANS IN CLIMATE CHANGES
  - -- OCEAN RESPONSE TO STRONG WIND FORCING
  - -- UNUSUAL OCEANIC PHENOMENON SUCH AS EL NINO
- o FLIGHT WOULD BE CONCURRENT WITH NASA'S SCATTEROMETER PLANNED FOR FLIGHT ON NROSS AND WITH THE WORLD OCEAN CIRCULATION EXPERIMENT (WOCE)

SENSORS:

NASA: DUAL CHANNEL RADAR ALTIMETER; MICROWAVE RADIOMETER; ADVANCED DOPPLER TRACKING SYSTEMS

CNES: SEASAT CLASS ALTIMETER; DORIS TRACKING SYSTEM

FLIGHT PARAMETERS: 1334 KM CIRCULAR ORBIT; 63.1° INCLINATION; 10 DAY EXACT REPEAT: ARIANE LAUNCHED, SHUTTLE RETRIVEABLE

STATUS:

- o JOINT DEFINITION STUDIES WITH CNES COMPLETE; COLLABORATIVE MISSION PROPOSED; SATELLITE DEFINITION STUDIES COMPLETED BY FAIRCHILD, RCA, AND ROCKWELL
- o BRASSBOARD OF TOPEX ATLIMETER NEARING COMPLETION
- o ANNOUNCEMENT OF OPPORTUNITY TO BE RELEASED IN LATE 1985

INTERNATIONAL SOLAR-TERRESTRIAL PHYSICS (ISTP) PROGRAM

MAJOR DISCIPLINE: SOLAR-TERRESTRIAL PHYSICS (SOLAR AND PLASMA PHYSICS)

PROGRAM GOAL: COMBINE RESOURCES AND SCIENTIFIC COMMUNITIES ON THE INTERNATIONAL SCALE TO UNDERTAKE A COMPREHENSIVE PROGRAM OF SOLAR-TERRESTRIAL RESEARCH TO MEASURE, TO MODEL, AND TO QUANTITATIVELY ASSESS THE PROCESSES IN THE SUN-EARTH INTERACTION CHAIN WITH EMPHASIS ON:

- SOLAR SEISMOLOGY
- CORONAL DYNAMICS
- SOLAR WIND ORIGIN AND THREE-DIMENSIONAL FEATURES
- SOLAR WIND-MAGNETOSPHERE INTERACTIONS
- GLOBAL PLASMA STORAGE, FLOW, AND TRANSFORMATION
- DEPOSITION OF ENERGY INTO THE ATMOSPHERE
- BASIC PLASMA STATES AND CHARACTERISTICS

ACCOMPLISHMENTS:

- REASSESSED THE PRIMARY ISTP SCIENCE OBJECTIVES AND REVISED THE SCIENCE MEASUREMENTS AND PROGRAM APPROACH
- DISCUSSED THE REVISED PROGRAM CONCEPT WITH THE ISTP SCIENCE TEAMS, OUR INTERNATIONAL PARTNERS AND ADVISORY COMMITTEES
- IDENTIFIED THREE PRODUCTION LINE SPACECRAFT SYSTEMS THAT CAN MEET THE NASA ISTP OBJECTIVES
- REDISTRIBUTED GROUND PROCESSING SCHEME TO DEPEND MORE ON INVESTIGATOR'S CAPABILITES
- FORMULATED A SIGNIFICANT NASA ISTP PROGRAM AT 60% OF THE FY86 NEW START LEVEL

STATUS:

- INSTRUMENT DEFINITION STUDIES UPDATED TO ACCOMODATE DESCOPING
- SYSTEM DEFINITION STUDIES CONDUCTED IN-HOUSE AND WITH JHU/APL; SUBSYSTEM STUDIES UNDERWAY WITH PHILCO FORD
- TRILATERAL PLANNING GROUP MEETINGS CONDUCTED WITH ISAS AND ESA

COMET RENDEZVOUS ASTEROID FLYBY (CRAF)

MAJOR DISCIPLINE:	SOLAR SYSTEM EXPLORATION
MISSION OBJECTIVES:	DETAILED STUDY OF A COMET NUCLEUS AND COMA, OBSERVE ASTEROIDS ENROUTE
RATIONALE:	EXPLORATION OF THESE PRIMITIVE OBJECTS WILL PROVIDE INSIGHTS INTO THE EARLY HISTORY AND FORMATION OF THE SOLAR SYSTEM. CRAF MISSION OFFERS OPPORTUNITY FOR "TIME-TRAVEL." RENDEZVOUS AND EXTENDED STATION-KEEPING WITH A SHORT-PERIOD COMET WILL PRODUCE A SIGNIFICANT SCIENTIFIC RETURN THAT CANNOT BE ACHIEVED BY FAST FLYBYS.
SENSORS:	IMAGING NEUTRAL AND ION MASS SPECTROMETERS DUST COLLECTOR AND ANALYZER DUST COUNTER IR REFLECTANCE MAPPING SPECTROMETER MAGNETOMETER AND PLASMA WAVE
FLIGHT PARAMETERS:	1991 SHUTTLE/CENTAUR G'LAUNCH DIRECT TRAJECTORY TO COMET WILD 2 ENROUTE FLYBY OF ASTEROID HEDWIG RENDEZVOUS WITH COMET WILD 2 ABOUT THREE YEARS PRIOR TO PERIHELION STATION-KEEPING/ORBITING OF COMET THROUGH PERIHELION
STATUS:	MISSION AND SPACECRAFT DEFINITION COMPLETED PRE-PROJECT DEVELOPMENTS INITIATED PRE-PROJECT INSTRUMENT DEVELOPMENT UNDERWAY

ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)

MAJOR DISCIPLINE: X-RAY ASTRONOMY

MISSION OBJECTIVES: DETAILED LONG-TERM STUDY OF X-RAY EMISSIONS FROM ASTRONOMICAL SOURCES

RATIONALE: MAJOR NATIONAL OBSERVATORY FOR X-RAY ASTRONOMY

- 100 TIMES MORE SENSITIVE THAN HEAO-2, TWICE THE SPECTRAL RANGE OF HEAO-2
- WILL PROVIDE NEW INSIGHTS IN COSMOLOGY, THE STUDY OF STELLAR STRUCTURE AND EVOLUTION, ACTIVE GALAXIES, AND CLUSTERS OF GALAXIES

HIGHEST PRIORITY RECOMMENDATION OF ASTRONOMY SURVEY COMMITTEE

SENSORS: FOUR FOCAL PLANE INSTRUMENTS ACCEPTED FOR DEFINITION:

- BRAGG CRYSTAL SPECTROMETER
- CCD IMAGER
- MICROCHANNEL PLATE DETECTOR
- X-RAY CALORIMETER

IN ADDITION, THERE ARE TWO SETS OF NON-FOCAL PLANE TRANSMISSION GRATINGS

FLIGHT PARAMETERS:
500 KM CIRCULAR ORBIT
28° INCLINATION
SHUTTLE LAUNCH AND SERVICE

STATUS:
FACILITY DEFINITION STUDIES BEGAN IN FY 1984
ANNOUNCEMENT OF OPPORTUNITY RELEASED 8/83
INVESTIGATION SELECTION 3/85
TECHNOLOGY MIRROR TESTS 6/85

GEOPOTENTIAL RESEARCH MISSION (GRM)

MAJOR DISCIPLINE:	GEODYNAMICS
MISSION OBJECTIVES:	DETERMINE THE EARTH'S GRAVITY AND MAGNETIC FIELDS TO PROVIDE ACCURATE MATHEMATICAL MODELS FOR STUDIES ON THE SOLID EARTH AND THE OCEANS.
RATIONALE:	GAIN AN UNDERSTANDING OF: o STRUCTURE AND EVOLUTION OF THE CONTINENTS o MANTLE CONVECTION AND ITS RELATION TO PLATE MOTION o MECHANICAL PROPERTIES OF LITHOSPHERE o CORE DYNAMICS AND THE ORIGIN OF THE MAIN MAGNETIC FIELD o IMPORVED METHODS IN ORBIT AND TRAJECTORY COMPUTATIONS o RELATIONSHIP OF GEOLOGICAL FEATURES STRUCTURE AND NATURAL RESOURCES DISTRIBUTION o REFERENCE SURFACE TO ASSIST IN DETERMINING MEAN OCEAN CIRCULATION
SENSORS:	DISTURBANCE COMPENSATION SYSTEM (DISCOS) SATELLITE-SATELLITE TRACKING SYSTEM VECTOR AND SCALAR MAGNETOMETERS
FLIGHT PARAMETERS:	160 KM POLAR ORBIT 100-600 KM VARIABLE SATELLITE SEPARATION SHUTTLE LAUNCHED
STATUS:	DATA ANALYSIS ANNOUNCEMENT OF OPPORTUNITY (TBD) MODEL INTERPRETATION ANNOUNCEMENT OF OPPORTUNITY (TBD)

LUNAR GEOSCIENCE ORBITER (LGO)

MAJOR DISCIPLINE:	SOLAR SYSTEM EXPLORATION
MISSION OBJECTIVE:	MEASURE GLOBAL ELEMENTAL AND MINERALOGICAL SURFACE COMPOSITION, ASSESS GLOBAL RESOURCES, MEASURE GLOBAL GRAVITY FIELD, FIGURE AND TOPOGRAPHY.
RATIONALE:	UNDERSTANDING OF THE VENUS-EARTH-MARS TRIAD INCLUDES THE MOON'S ROLE IN EARTH'S DEVELOPMENT. THIS LUNAR KNOWLEDGE CAN BE EXTENDED TO UNDERSTAND MANY PLANETARY BODIES. THE MOON IS LARGELY UNEXPLORED FROM GEOLOGICAL, GEOCHEMICAL, AND GOEPHYSICAL POINTS OF VIEW.
SENSORS:	IR REFLECTANCE MAPPING SPECTROMETER X-RAY AND GAMMA RAY SPECTROMETER RADAR ALTIMETER MAGNETOMETER AND ELECTRON REFLECTOMETER DOPPLER TRACKING
FLIGHT PARAMETERS:	INITIAL ELIPTICAL ORBIT, LESS THAN 30 KM PERIAPSIS LATER 100 KM CIRCULAR POLAR ORBIT ONE YEAR AT MOON SHUTTLE/TOS LAUNCH
STATUS:	DEFINITION STUDIES UNDERWAY SAME SPACECRAFT AS MARS OBSERVER REFLIGHT OF MANY MARS OBSERVER INSTRUMENTS

SPACE INFRARED TELESCOPE FACILITY (SIRTF)

MAJOR DISCIPLINE: INFRARED ASTRONOMY

MISSION OBJECTIVES: DETAILED STUDY OF INFRARED ASTRONOMICAL SOURCES

RATIONALE: PROVIDES NECESSARY FOLLOW THROUGH TO SUCCESS AND DISCOVERIES OF IRAS SURVEY

- UP TO 1000 TIMES GREATER SENSITIVITY, 10 TIMES GREATER SPATIAL RESOLUTION THAN IRAS
- THE INSTRUMENT COMPLEMENT INCLUDES A CAMERA, A SPECTROMETER, AN IMAGING PHOTOMETER

FLIGHT PARAMETERS:
(DESIRED)
>700 KM CIRCULAR ORBIT
98° INCLINATION
SHUTTLE LAUNCH AND SERVICE

(OPTION)
SPACE STATION PLATFORM UNDER EVALUATION

STATUS:
ANNOUNCEMENT OF OPPORTUNITY RELEASED 5/83
INVESTIGATION SELECTION 6/84
FACILITY DEFINITION STUDIES BEGINNING IN FY 1986

GRAVITY PROBE-B

MAJOR DISCIPLINE:	RELATIVITY
MISSION OBJECTIVES:	TWO TESTS OF EINSTEIN'S GENERAL THEORY OF RELATIVITY O GEODETIC PRECESSION OF ORBITING GYROSCOPE DUE TO PROXIMITY OF EARTH'S MASS O MOTIONAL PRECESSION OF "FRAME DRAGGING" OF SPACE/TIME DUE TO SPIN OF EARTH'S MASS
RATIONALE:	GENERAL THEORY OF RELATIVITY ONE OF MOST FAR REACHING, LEAST TESTED THEORIES OF MODERN PHYSICS NECESSARY COMPONENT TECHNOLOGIES ARE NOW IN PLACE: O LOW MAGNETIC FIELDS (10^{-7} GAUSS) O LOW, STABLE TEMPERATURE (1.6° K) O ULTRAPRECISE ROTORS (SPHERICITY TO 10^{-6} INCH) O DRAG-FREE SPACECRAFT (10^{-10} G) O ELECTROSTATIC ROTOR SUSPENSION
SENSORS:	SMALL, CRYOGENICALLY COOLED, QUARTZ GYROSCOPES AND STAR-TRACKING TELESCOPE
FLIGHT PARAMETERS:	600 KM CIRCULAR ORBIT 90° INCLINATION STS LAUNCH
STATUS:	PHASE A STUDIES COMPLETED PHASE B INSTRUMENT STUDIES IN PROGRESS

EARTH OBSERVING SYSTEM (EOS)

MAJOR DISCIPLINE: EARTH SCIENCE (MULTIDISCIPLINARY)

MISSION OBJECTIVES: IMPROVED SCIENTIFIC UNDERSTANDING OF THE EARTH AS A SYSTEM

RATIONALE: UTILIZATION OF A SPACE PLATFORM TO ACQUIRE LONG-TERM MEASUREMENTS ON A GLOBAL SCALE

EARTH SENSING INSTRUMENTS TO PROVIDE INTERDISCIPLINARY INFORMATION ON:

- HYDROLOGIC PROCESSES
- BIOGEOCHEMISTRY
- CLIMATOLOGICAL PROCESSES
- ATMOSPHERIC PROCESSES/CHEMISTRY
- OCEANIC PROCESSES
- SOLID EARTH COMPOSITION

SENSORS: INITIAL ORBITING CONFIGURATION:

- MODERATE RESOLUTION IMAGING SPECTROMETER
- HIGH RESOLUTION IMAGING SPECTROMETER
- HIGH RESOLUTION MULTIFREQUENCY MICROWAVE RADIOMETER
- LASER ATMOSPHERIC SOUNDER AND ALTIMETER
- SYNTHETIC APPERTURE RADAR

PLUS EVOLUTIONARY ADDITIONAL PAYLOAD

FLIGHT PARAMETERS: 730 KM CIRCULAR ORBIT
SUN-SYNCHRONOUS, 2:00 P.M. EQUATOR CROSSING TIME
POTENTIAL USE OF SPACE STATION POLAR PLATFORM

STATUS: SCIENCE AND MISSION REQURIEMENTS WORKING GROUP REPORT COMPLETED
INSTRUMENT STUDIES INITIATED
PHASE-A STUDY IN PROGRESS

GEOSTATIONARY PLATFORM

MAJOR DISCIPLINE: COMMUNICATIONS

MISSION OBJECTIVE: ENSURE CONTINUED PREEMINENCE OF THE U.S. IN GEOSTATIONARY SPACE TECHNOLOGY, AND FULLY EXPLOIT SPACE SHUTTLE AND SPACE STATION CAPABILITIES.

RATIONALE: THE GEO PLATFORM WILL EMPLOY MULTIPLE LARGE ANTENNAS TO MAKE POSSIBLE ADVANCED MOBILE COMMUNICATIONS AND PROVIDE INTERCONNECTIVITY AND FREQUENCY REUSE WITH MULTIPLE STATIONARY AND ELECTRONICALLY HOPPED BEAMS. SCIENTIFIC EXPERIMENTS MAY BENEFIT BY USING THE GEO PLATFORM, ITS COMMUNICATIONS CAPABILITIES, AND LARGE APERTURE ANTENNAS FOR PLASMA PHYSICS, SPACE TRACKING, AS WELL AS A VARIETY OF REMOTE SENSING PAYLOADS. THE GEO PLATFORM WILL ALSO DERIVE THE DEVELOPMENT OF SPACE ASSEMBLY TECHNOLOGY NEAR THE SPACE STATION.

PAYLOADS: CURRENTLY UNDETERMINED; WILL PROBABLY INCLUDE:

- MOBILE COMMUNICATIONS
- DIRECT BROADCAST
- FIXED COMMUNICATIONS
- REMOTE EARTH SENSING
- RADIOMETER
- SPACE TRACKING
- NODEL ON-BOARD SIGNAL PROCESSING AND SWITCHING CENTERS

FLIGHT PARAMETERS: GEOSTATIONARY ORBIT 35,000 KM

STATUS: AWARD PHASE A CONTRACTS IN FY 1984
ADVANCED TECHNOLOGY DEVELOPMENT PLANNED FOR FY 1985 - 1988

SATURN ORBITER TITAN PROBE ("CASSINI")

MAJOR DISCIPLINE: SOLAR SYSTEM EXPLORATION

MISSION OBJECTIVES: DETAILED STUDY OF SATURN'S ATMOSPHERE, RINGS AND OF TITAN'S ATMOSPHERE AND SURFACE MORPHOLOGY

RATIONALE: TO PROVIDE AN UNDERSTANDING OF THE BEHAVIOR OF SATURN'S COMPLEX SYSTEM NOT POSSIBLE WITHOUT INVESTIGATION OVER AN EXTENDED PERIOD OF TIME.

MAPPING AND EXPLORATION OF TITAN, AN AEROSOL SHROUDED BODY THOUGHT TO BE SIMILAR TO OUR PRE-BIOTIC EARTH, DURING 25 ENCOUNTERS BY ORBITER PLUS TITAN ENTRY PROBE.

SENSORS:

SATURN: IMAGING, IR AND UV RADIOMETERS, PLASMA WAVE, MAGNETOMETER, CHARGED PARTICLES, DUST DETECTOR, RADIO SCIENCE

TITAN: ION AND NEUTRAL MASS SPECTROMETERS; RETARDING POTENTIAL ANAYLZER; ELECTRON TEMPERATURE PROBE; PRESSURE, TEMPERATURE AND ACCELERATION SENSORS; NEPHELOMETER, GAS CHROMATOGRAPH, RADIOMETER, RADAR MAPPER, RADIO SCIENCE

FLIGHT PARAMETERS:

1994 SHUTTLE/CENTAUR G'LAUNCH ON DELTA VEGA TRAJECTORY

INSERTION INTO SATURN ORBIT AND DEPLOYMENT OF PROBE DURING TITAN FLYBY

THREE YEAR SATELLITE TOUR INCLUDES 25 CLOSE TITAN ENCOUNTERS

STATUS:

JOINT ESA/NASA ASSESSMENT STUDY UNDERWAY

- O US PROVIDED ORBITER, LAUNCH, MISSION OPERATION
- O ESA PROVIDED PROBE, PROBE OPERATIONS
- O US, EUROPEAN INSTRUMENTS ON BOTH ORBITER AND PROBE

PRELIMINARY SPACECRAFT STUDIES UNDERWAY

OSSA OFFICE OF SPACE SCIENCE AND APPLICATIONS MAJOR SHUTTLE MISSIONS

MSL-2	12/85
ASTRO-1	3/86
ULYSSES	5/86
GALILEO	5/86
MSL-4	6/86
HST	8/86
EOM-1/2	9/86
SPARTAN-2	10/86
MSL-5	10/86
ASTRO-2	10/86
SLS-1	2/87
SRL-2 (SIR-B REFLIGHT)	2/87

OSSA

CURRENT OSSA SPACE STATION ACTIVITIES

DEVELOPING SPACE STATION UTILIZATION PLANS

- BUDGET
- IOC MISSION PLAN (1992-94)
- POST IOC MISSION PLAN (1994-2000)
- ENGINEERING AND INTEGRATION REQUIREMENTS DOCUMENT
- OPERATIONS PLAN

MAJOR DEFINITION AND CONFIGURATION STUDIES

- SERVICING AND REPAIR
- POLAR PLATFORM
- LABORATORY MODULES
- ATTACHED PAYLOADS
- COORBITING PLATFORM(S)
- GEOSTATIONARY PLATFORM (POST IOC)

OSSA OFFICE OF SPACE SCIENCE AND APPLICATIONS
PLANNING ISSUES — 'BALANCE'

- SPACE SCIENCE
  - ASTROPHYSICS
  - PLANETARY
  - EARTH SCIENCE
  - LIFE SCIENCE
  - MICROGRAVITY SCIENCE
- COMPETING DISCIPLINES
  - TRADITIONAL
    - ASTRONOMY AND ASTROPHYSICS
    - PLANETARY EXPLORATION
    - SOLAR AND SPACE PHYSICS
    - COMMUNICATIONS
  - EMERGING
    - MICROGRAVITY SCIENCE AND APPLICATIONS
    - EARTH SCIENCE
- SATELLITES, SHUTTLE, PLATFORMS, AND SPACE STATION
- APPLICATIONS
  - COMMUNICATIONS
  - REMOTE SENSING
  - MATERIALS PROCESSING

Mr. NELSON. All right. I would like for you to stay at the table as we talk to everybody else.

But in the meantime, Mr. Brown, Mrs. Meyers, do you all have any further questions?

Mr. BROWN. I have two questions, but I will defer them. Thank you, Mr. Chairman.

Mrs. MEYERS. No questions at this time, Mr. Chairman.

Mr. NELSON. We will hear next from Mr. Robert Aller, Associate Administrator for the Office of Space Tracking and Data Systems.

Please proceed, Mr. Aller.

STATEMENT OF ROBERT O. ALLER, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE TRACKING AND DATA SYSTEMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. ALLER. Thank you, Mr. Chairman. It is a pleasure for me to come over here and talk about our planning.

It's an interesting progression you're going through this morning, it seems to me. You've heard from all of my customers with the previous testimony, and all of us are Mr. Nysmith's customers. So it's kind of interesting to look at that progression.

Our planning cycle is driven principally by two things. We maintain facilities and capabilities to support our Aeronautics and Space Program, and that in itself is a planning cycle to assure we maintain proper technology in those areas.

The other prime driver, of course, are the kinds of programs that Dr. Edelson has just discussed with you, as well as the kinds of major programs like the shuttle and the space station.

Could I have the first Vu-Graph, please?

I will very briefly, just to remind the subcommittee in this rather mundane area, after listening to Dr. Edelson's very interesting discussion of science and applications, indicate what we're responsible for and planning for are the items indicated in figure 1.

If I could have the next chart, please.

[Figure 2.]

That describes the particular facilities that are necessary to support our program. We've talked many times—the first bullet simply indicates we have several ground networks. The major ground network we will have in the future will be the deep-space network that supported the Giacobini-Zinner encounter last week so nicely. Those are the three stations at Madrid, Goldstone, and Australia. And we will be upgrading those in the near future.

The other major network that we have, of course, is the space network that we're initiating with TDRSS, and that network I will talk a little bit more about. We, of course, will continue that into the future beyond the year 2000. We have communications facilities necessary to tie all of those together.

And then the last bullet indicates the control facilities for the free flyers in Burt's program as well as the mission operations. The trajectory work that was done, as an example, on the ISEE program, was done with the facilities and the operators we maintain at Goddard.

Next chart, please.

I will just skip through figure 3.

Our planning process in NASA generally follows objectives both near-term and long term, and those simply indicate our longer-term, broader objectives.

[Figure 4.]

We do have some very interesting milestones coming up in the very near future. We have—it's interesting, Burt and I were talking just before the session—we have coming up in January, on the 22nd of January, we're planning to launch the next TDRSS as well as the teacher-passenger, and on the 24th of January we have the Uranus encounter, a magnificent Voyager encounter that I am looking forward to very much, and, of course, we will be supporting with the deep-space network.

Next slide, please.

[Figure 5.]

Mr. NELSON. Now, I didn't follow that, what you said about the teacher.

Mr. ALLER. The teacher, we plan to fly the teacher on the flight that happens to be deploying our next TDRSS, but it's the January 22 flight.

Mr. NELSON. I see.

Mr. ALLER. The ground network planning, as shown in figure 6, we will be phasing out the 25 years of ground network operation in the agency. We have been doing that for several years. I should point out that although we do not have an operational TDRSS at this point, over the past 5 years we have phased out over 50 percent of that network in manpower and in facilities as well as civil service manpower. That network will be phased out over the next year.

The planetary mission support will, of course, continue in the deep-space network complexes and the upgrades that are indicated below there on this facility will go on into the 1990's.

The major upgrades that we're looking at—could I have the next slide, please?

You've seen the chart on your right (figure 7) and the chart on the left (figure 8) indicates what one of our deep-space net sites looks like in Australia. You may have seen that site before. The large antenna in the middle is the large 64-meter antenna. There are the 26-meter and two 34-meter antennas.

The chart on your right, (figure 9) indicates at Australia how we are arraying that facility along with the Parkes facility in Australia for the Uranus encounter in January. Basically, we're combining electronically the signal we receive at all of these sites simultaneously to increase the data rate on that particular mission.

During the next 5 years we will be furthering that arraying capability.

Could I have the next slide, please?

By the time the Voyager spacecraft passes Neptune in the year 1989, at Goldstone, which has a similar set of arrays as in the Australian site, we will be arraying it with the Socarro astronomy site, which has 27 25-meter antennas. These will all be arrayed simultaneously with our three large antennas at Goldstone to receive the very weak signal we will be returning from the planet Neptune.

That is the kind of upgrade, and that is the major engineering upgrade, we will be accomplishing on the deep-space network—next slide, please—over the next 5 years.

Figure 10 depicts the missions that NASA's ground network will be supporting through the year 1991.

Next slide, please.

Getting to the space network and the TDRSS Program, figure 11 on your left simply reminds you of what the TDRSS Program operational configuration is intended to be. We have in orbit the green satellite in the east. In January we hope to launch—we will launch the yellow satellite that will be placed in the western position. And in July we will launch the third satellite which will be located in the spare position. We will then have an operational configuration of TDRSS. And that's what figure 12 on your right in our planning indicates.

The six spacecraft that we have in the program will carry us through our full operating capability, we estimate, through the year 1994. Of course, the remaining spacecraft are ground spares, and we will launch them as the requirement arises, to replace the satellites.

In our planning to maintain a space network, of course, we will be replacing those six spacecraft. We also are planning a redundant site, a second site in the White Sands ground station area, to support both these spacecraft and the follow-on spacecraft. It will be a backup to the White Sands site for the vulnerability of that particular single site as well as provide a capability to support more than two fully operational satellites in orbit.

Our present ground station only allows us to operate the green and the yellow fully in orbit.

Mr. BROWN. What is that ground station?

Mr. ALLER. The ground station is the White Sands ground station located outside Las Cruces, NM.

Mr. BROWN. Is that what's depicted on your chart?

Mr. ALLER. That's not a very good geographical representation, that's true. [Laughter.]

But that's where it is, yes, sir.

Mr. NELSON. Your operational maximum then is with two TDRSS operating?

Mr. ALLER. Two TDRSS operating.

Mr. NELSON. With one up as a spare.

Mr. ALLER. With one up as a spare.

Mr. NELSON. Now the——

Mr. ALLER. We maintain—excuse me?

Mr. NELSON. Does that give you total contact with the shuttle as it orbits the Earth?

Mr. ALLER. The geographical limitation we have with the single ground site is,—there will be a gap, so-called gap, over the Indian Ocean—that we can't locate the satellites far enough east and far enough west to totally cover the gap and still see it from a single ground site. So we have about a 10-degree gap that occurs over India and the Indian Ocean. And I will show you that on an upcoming slide here in just a moment.

Mr. NELSON. And you say your plans are to have another ground station to cover that gap?

Mr. **Aller**. No, sir; we don't plan to close that gap at all. Our plans are to locate a second ground site very close to the one we have that allows us to take advantage of the infrastructure we have of that facility for operating a second site. And it will back up this location.

Our plans are, in the future—and I will get into that in just a moment—to locate two satellites in the east and two satellites in the west and operate four satellites fully to provide ready antenna coverage in those areas where we need it.

As we looked into the future, we found that the problems associated with the gap were really not a problem. It's a lack of coverage for about 15 percent of an orbit for low Earth orbit. Of course, as you go up, that gap closes the higher in altitude you get. To about, I think it is, 10,000 miles, there is no gap, because you can see over the Earth's horizon from there.

Mr. **Nelson**. Go ahead, George.

Mr. **Brown**. Can you translate that gap into minutes? Is that about a 5-minute gap?

Mr. **Aller**. It's about a 10-minute gap. If you take a 90-minute orbit, it will be about a 10-minute gap in that orbit.

Mr. **Nelson**. And you say you're going to have four up at one time, but you're only using two?

Mr. **Aller**. No, sir; in our longer range plans we will be using two with the present configuration at the end of next year, from a single ground site at White Sands.

Mr. **Nelson**. Right.

Mr. **Aller**. That ground site is so constructed that we can only fully operate those two. We are planning to provide a second ground site in that area that can see the same locations of satellites eventually, in the mid-1990's, to meet the traffic load of what I call the space station era.

Mr. **Nelson**. I see.

Mr. **Aller**. We will put two additional satellites in those locations and will operate both satellites in the east and both satellites in the west, giving us, rather than four operational antennas in space, we will have eight. And that's the longer range plan.

Mr. **Brown**. Is the military using these, or do they have a separate set of satellites for their purposes?

Mr. **Aller**. We support the DOD, Mr. Brown.

Mr. **Nelson**. Now, part of the reason——

Mr. **Aller**. That's not a full answer to your question, and I can't—I don't have the full answer. But we do support DOD.

Mr. **Brown**. I will get the full answer later.

Mr. **Nelson**. Part of the reason for having TDRSS in the first place was that you had, for all the data that we were accumulating on things like spacelab and then the space station, that you have the ability then to transmit that data instantly instead of having it stored on tape and bringing it back.

Mr. **Aller**. Yes, sir.

Mr. **Nelson**. All right. So you've got a 10-minute gap every 1½ hours. What was your thinking that is the tradeoff that you're willing to take that 10-minute gap out of every 90 minutes?

Mr. **Aller**. Well, the tradeoff—first of all, everything being equal, we would like to provide full coverage. We would like to close the gap. However, the data lost in the gap has not proven to date and, in looking at our programs over the next 10 years, is not a significant problem in the data gathering and the data retrieval.

We have to remember, with the single TDRSS our whole operational productivity has gone up immensely. With a single TDRSS in orbit it allows us, I think most dramatically in the shuttle missions, to cover roughly 45 minutes continuously of that orbit.

We had some insight into this back in the ASTP Program when we used ATS for TV coverage, you may remember, on that particular program. It was our first utilization from low Earth orbit of communicating through a satellite for health and safety as well as video data on a mission. It's an immense increase in coverage.

We do not cover users normally for an entire orbit. Most users of TDRSS use it for 5 minutes, 10 minutes, 20 minutes, different segments in their orbit where they are most demanding of their coverage.

The shuttle, as an example, doesn't require full coverage. The shuttle was flying well before TDRSS was in orbit, and will be before the two.

It provides flexibility in the operation planning. It certainly has contributed to the astounding recoveries, retrievals, repairs that we have been able to accomplish on the program by having that kind of coverage.

The lack of coverage in one area of the Earth is only a problem if there is a requirement in real time to look at something in that particular area and transmit it in real time. And we don't have that problem in NASA.

Mr. **Nelson**. Please continue.

Mr. **Aller**. OK, could I have the next slide, please?

[Figure 13.]

Here I talk a little bit more about what we've already covered.

Could I keep the chart up on the right, please?

This is a rather technical chart. This, figure 13, really shows what is not covered rather than what is covered.

The single TDRS we have in orbit now is located to the right there where it says "2-TDRS east." We have one in that location. So effectively, we have two of our single-access antennas that can point at users.

We also have a multiple access system that can cover 20 users simultaneously. Our high data rate users such as shuttle, such as Landsat, such as space telescope, those kinds of programs, we only have two antennas on each vehicle. So the little number "2" in parentheses indicates that we have two antennas in space right now.

Those two antennas can see everything on that chart that is white. What it cannot see are the yellow areas.

When we put up the vehicle in January, we will be able to see all of the area except the little wedge that's shown as zero over the Indian Ocean. That wedge is an area that neither the eastern nor western satellite can see. But once we have the second vehicle operating, the coverage of the Earth is all except that little wedge that appears in there.

Now, our planning in the future is to place two in the east and two in the west, and the numbers in parentheses are the numbers of antennas we have available for that area of the Earth with our present configuration, and the numbers "4, 8, 4, 0, 4" are the numbers of antennas we will have, with two in each location, operating from two ground stations.

So that is our plan as we get into the early '90s for the space network, and that planning will be proceeding through the latter half of this decade as we prepare that second ground station and get into a program for the follow-on spacecraft.

I think that covers that chart. Could I have the next one, please?

Here I have shown in figure 14 simply through 1992 the kinds of programs that are dedicated to the space, to the TDRSS or space network coverage, the kind of programs that we have in orbit now as well as those that will come in the future. The difference in bars is simply the terminology we use internal to NASA. When we extend mission lifetimes, we extend it as indicated on the chart.

Next slide, please.

[Figure 15.]

We plan for our full capability to be available in the year 1992 in preparation for the initial space station launches.

Very quickly, our planning then in our other areas, which are communications, mission control, and data handling in the future. Under communications our communications network are commercial networks. We have two networks. One I maintain for operational purposes only, and one for administration purposes. These networks basically lease commercial services.

We're very interested, for instance, in the fiber optics, fiber cabling techniques that Burt was discussing. They are very useful for high data rate transfer. The difficulties they have, of course, is routing, routing those fiber cables to the areas you need it. That's the advantage we have with our satellite coverage through communications satellites.

So our communications system is basically growing with the technology, which is fantastic in telecommunications. We utilize commercial capability basically for our communications in NASA.

In mission control and handling, I would like to indicate here that we provide all the mission control and the data, the initial data handling, the orbital trajectory work for Dr. Edelson's program, and that leads directly into my next chart, figure 16, which is the next major planning area for this program.

That's what we call the customer data and operations system. That is the standard kind of support we provide programs as we look into the space station era.

We do what we call data capture and processing. Basically, if I could trace from a space station, for instance, the data that will come in through a TDRSS satellite to White Sands and be transferred to this facility—we have not decided where that will be yet; most likely, a significant portion of it will be at the Goddard Space Center, where we focus these activities—where we do some processing to order that data, and of course, the communications necessary then to distribute to the users of the space station.

It appears it will be a significant engineering effort in support of that major program.

Next slide, please.

Mr. **Nelson**. Will EOSAT transmit through TDRSS?

Mr. **Aller**. No, sir, it will not.

I should bring up a point that you asked us to discuss somewhat. We are looking into a future in the 1990's where, in my view, we will be operating internationally, in international operations. We are seeing some of that, of course, driven principally by programs and cooperation in programs.

The facts are that we, of course, have a space network that is operating now. We will have full operational capability by the end of next year. The Europeans are planning a program. As a matter of fact, while you're visiting our friends in the U.S.S.R., I will be in Paris discussing their program with them.

The Japanese are planning a space network. And of course, the U.S.S.R. has announced a space network that was originally to be operational next year. I understand now that that has been delayed till 1989.

But we're looking into a timeframe in the 1990's where there will be significant space network capability available around the world. And we are initiating our planning to operate with those networks in conjunction with our own. It will be, I believe, a truly international networking of this capability.

Very, very briefly then, figure 17, our planning carries us slightly beyond the year 2000, and we have a couple of major efforts there in support of the agency I would like to touch on briefly.

Next chart, please.

In the space network figure 18, our planning carries us to around the year 2000, where the follow-on to the TDRSS, we're looking at a buy of about three spacecraft that will carry us to the year 2000. Beyond the year 2000, figure 19, we're looking at an upgrade of that system that will close the gap that we were discussing and provide significant increased capability.

One of the limitations on the TDRSS Program today is that we transmit all of our data to White Sands. One of the things we would look at in the future is the ability to transmit that data directly to a user on the ground rather than through a single point.

We are looking at higher data rates in the future, into laser technology that could be useful to the TDRSS Program around the year 2000.

Next chart, please.

[Figure 20.]

The other major upgrade we're looking at in capability is, in the ground network we are presently upgrading the system from S-band to X-band, and in the late 1990's we're looking to upgrade the X-band capability to K-band.

What we can do at these as we go to higher and higher frequencies, I described to you the arraying we will do at Neptune with those 27 antennas at Socorro and the three major antennas we have at Goldstone. By converting that one Goldstone antenna—the 64 meter then will be 70-meter antennas—to K-band, that is more than the equivalent of all those arrayed antennas at that frequency.

So we're looking to get into K-band in the mid-1990's, and beyond the year 2000 we're looking out to the possibility of a geosynchronous platform that could combine the capability of both the deep-space network and the TDRSS.

Next slide, please.

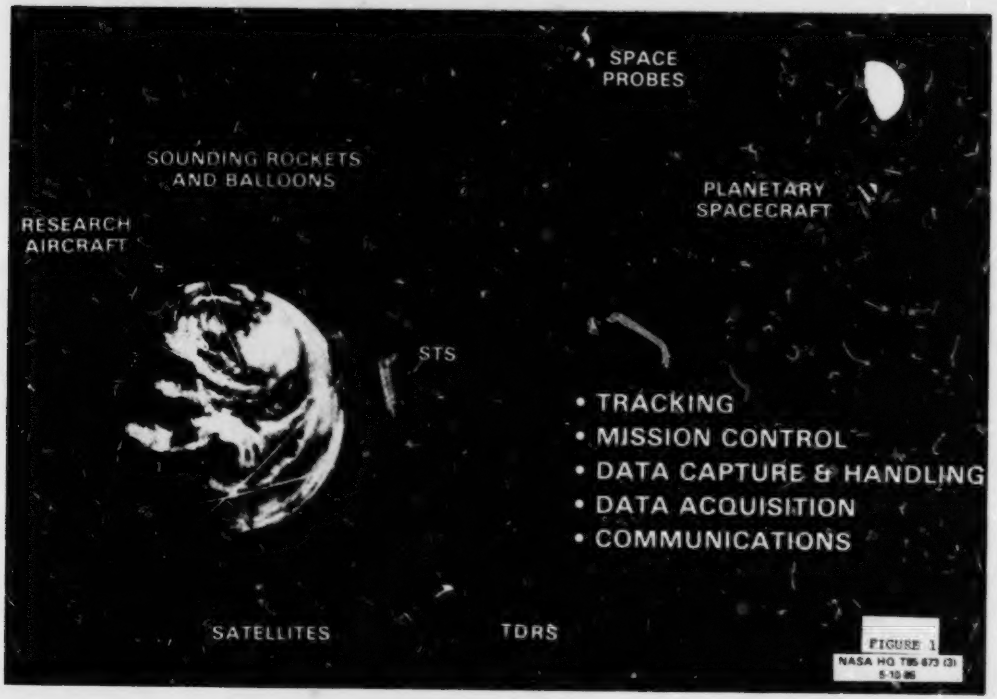
[Figure 21.]

This planning that I very briefly discussed with you is shown in a timeframe on this chart which indicates the present space network we plan to operate through about the year 2000, with the major capability to support space station coming on line about 1994, the K-band frequency upgrade to deep-space network about the 1998–99 timeframe, going into a new technology in the space network about the year 2000, and looking around the year 2010 for a geosynchronous platform that we could combine both capabilities of the deep-space network as well as the low Earth orbit network.

That's all I have, Mr. Chairman.

[Statement of Mr. Aller follows:]

TRACKING AND DATA ACQUISITION FUNCTIONS


SPACE PROBES
SOUNDING ROCKETS AND BALLOONS
PLANETARY SPACECRAFT
RESEARCH AIRCRAFT
STS
SATELLITES
TDRS

- TRACKING
- MISSION CONTROL
- DATA CAPTURE & HANDLING
- DATA ACQUISITION
- COMMUNICATIONS

FIGURE 1

NASA HQ T85-673 (3)
5-10-86

SPACE TRACKING AND DATA SYSTEMS

MAJOR FACILITIES USED TO ACCOMPLISH NASA FUNCTIONS:

- A NETWORK OF GROUND STATIONS TO COMMUNICATE WITH EARTH ORBITING AND DEEP SPACE MISSIONS: "THE GROUND NETWORK"
- A SERIES OF GEOSTATIONARY SATELLITES CURRENTLY BEING DEPLOYED WHICH WILL REPLACE GROUND STATION SUPPORT TO EARTH ORBITING MISSIONS ONCE IN PLACE: "THE SPACE NETWORK"
- COMMUNICATIONS FACILITIES AND SERVICES TO CONNECT THE GROUND AND SPACE NETWORK TO CONTROL CENTERS AND DATA FACILITIES
- COMPUTING FACILITIES TO CAPTURE, MERGE AND COLLATE DATA COLLECTED BY THESE NETWORKS IN PREPARATION FOR ITS DISTRIBUTION
- FACILITIES FOR SPACECRAFT AND MISSION OPERATIONS CONTROL

NASA HQ T86-082 (1)
5-10-86

FIGURE 2

MAJOR PROGRAM OBJECTIVES

- PROVIDE RESPONSIVE, COST EFFECTIVE TRACKING AND DATA SYSTEMS SUPPORT OF ONGOING AND APPROVED MISSIONS
- PROVIDE FOR A TDRSS FOLLOW-ON SYSTEM TO ASSURE CONTINUITY OF THE SPACE NETWORK
- AUGMENT T&DA CAPABILITIES FOR SUPPORT IN THE SPACE STATION ERA
  - SPACE NETWORK
  - DATA SYSTEMS
  - COMMUNICATIONS
- COMPLETE ARRAYING OF THE GROUND NETWORK IN PREPARATION FOR NEPTUNE ENCOUNTER
- PROMOTE STRONG ADHERENCE TO NASA DATA STANDARDS
- CONDUCT STUDIES AND DEVELOPMENTS AIMED AT IMPROVED SUPPORT OF FUTURE MISSIONS

NASA HQ [illegible]
REV [illegible]

FIGURE 3

1986 MILESTONES

- BRING SPACE NETWORK TO FULL OPERATIONAL CAPABILITY
- COMPLETE SECURITY CERTIFICATION OF SPACE NETWORK
- PHASE DOWN GROUND NETWORK
  - TRANSFER GREENBELT STATION TO WALLOPS
- COMPLETE TEST AND VERIFICATION OF SPACE TELESCOPE OPERATIONS MANAGEMENT SYSTEM
- COMPLETE UPGRADE AND INITIAL ARRAYING OF THE DSN
  - ICE G-Z ENCOUNTER
  - VOYAGER URANUS ENCOUNTER
  - GIOTTO, PATHFINDER/HALLEY'S COMET
  - GALILEO, ULYSSES MISSIONS
- PROVIDE INTEGRATED COMMUNICATIONS NETWORK FOR PROGRAM SUPPORT

FIGURE 4

PLANNING INTO THE 1990's

NASA HQ [illegible] (1)
[illegible]
FIGURE 5

PLANNING INTO THE 1990'S

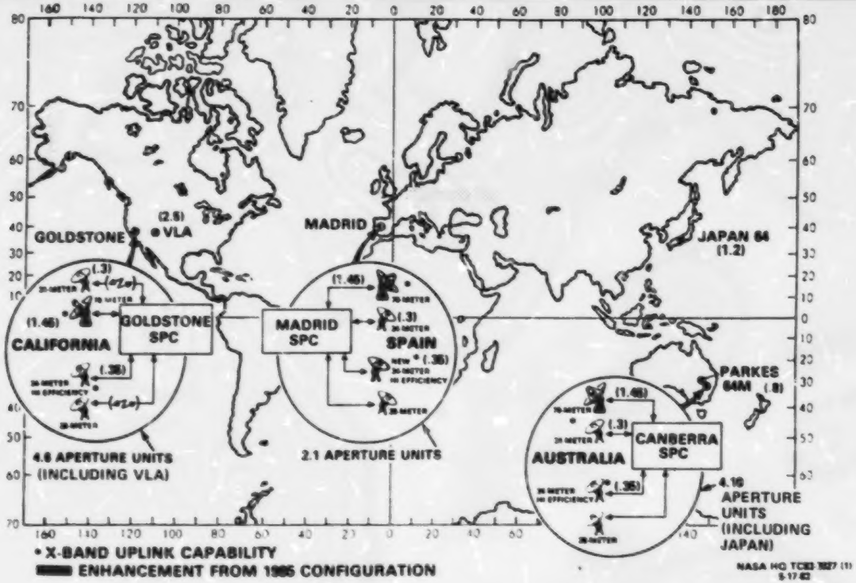
GROUND NETWORK

- WITH TDRSS OPERATIONAL, PHASE OUT EARTH ORBITAL GROUND NETWORK STATIONS
- PLANETARY MISSION SPACECRAFT WILL CONTINUE TO BE SUPPORTED BY THREE EXISTING PRIMARY DEEP SPACE NETWORK (DSN) STATION COMPLEXES
  - COMPLETE DSN ANTENNA UPGRADES
  - ACHIEVE OPERATIONAL X-BAND CAPABILITY AS PRIMARY COMMUNICATIONS FREQUENCY
  - INCREASE EFFECTIVE ANTENNA APERTURE BY COMBINING SIGNALS RECEIVED FROM SEVERAL ANTENNAS INCLUDING SOME OUTSIDE NASA
  - SUPPORT SCIENCE RETURN FROM PLANETARY MISSIONS
    - VOYAGER/URANUS, NEPTUNE ENCOUNTERS
    - GALILEO
    - VENUS RADAR MAPPER

NASA HQ T85-676 (1)
5-10-85

FIGURE 6

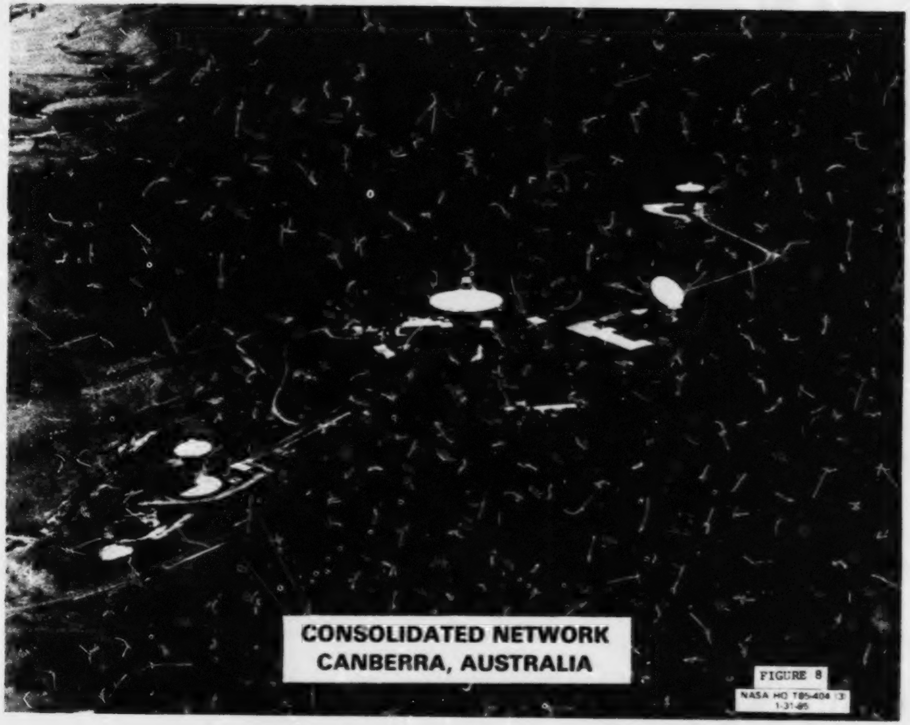
1989 VOYAGER/NEPTUNE & GALILEO SUPPORT CONFIGURATION


GOLDSTONE
(2.5)
• VLA
MADRID
JAPAN 64
(1.2)
(.3)
34-METER
70-METER
(1.46)
CALIFORNIA
GOLDSTONE SPC
(.35)
34-METER HI EFFICIENCY
(0.20)
(0.20)
26-METER
4.6 APERTURE UNITS (INCLUDING VLA)
(1.46)
70-METER
MADRID SPC
(.3)
34-METER
SPAIN
NEW • (.35)
34-METER HI EFFICIENCY
26-METER
2.1 APERTURE UNITS
PARKES 64M (.8)
(1.46)
70-METER
(.3)
34-METER
AUSTRALIA
CANBERRA SPC
(.35)
34-METER HI EFFICIENCY
26-METER
4.16 APERTURE UNITS (INCLUDING JAPAN)
• X-BAND UPLINK CAPABILITY
▬ ENHANCEMENT FROM 1985 CONFIGURATION

NASA HQ TC83-3027 (1)
5-17-83

FIGURE 7

161



CONSOLIDATED NETWORK
CANBERRA, AUSTRALIA

FIGURE 8

NASA HQ T85-404 (3)
1-31-85

FIGURE 9

NASA HQ TC85-1272(3) 9/26/85

GROUND NETWORK
MISSION SUPPORT PLANS

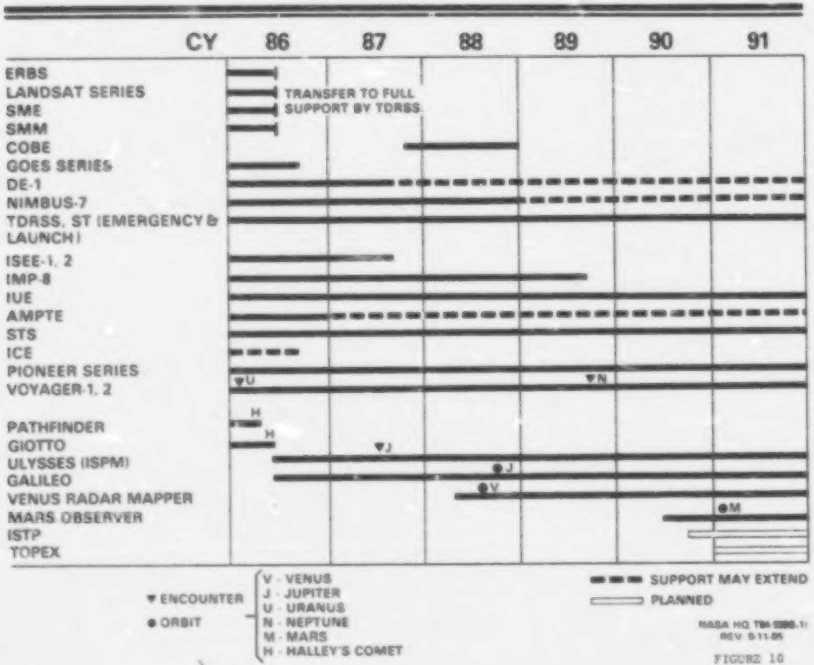


FIGURE 10

TRACKING AND DATA RELAY SATELLITE SYSTEM (TDRSS)

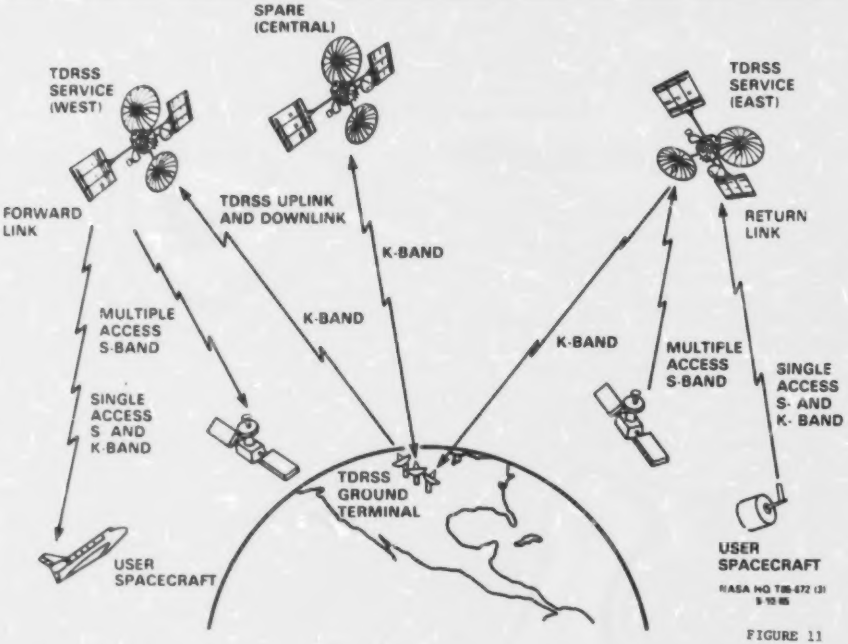

SPARE
(CENTRAL)
TDRSS
SERVICE
(WEST)
TDRSS
SERVICE
(EAST)
FORWARD
LINK
TDRSS UPLINK
AND DOWNLINK
K-BAND
RETURN
LINK
MULTIPLE
ACCESS
S-BAND
K-BAND
K-BAND
MULTIPLE
ACCESS
S-BAND
SINGLE
ACCESS
S- AND
K- BAND
SINGLE
ACCESS
S AND
K-BAND
TDRSS
GROUND
TERMINAL
USER
SPACECRAFT
USER
SPACECRAFT
NASA HQ T85-672 (3)
5-10-85

FIGURE 11

PLANNING INTO THE 1990'S

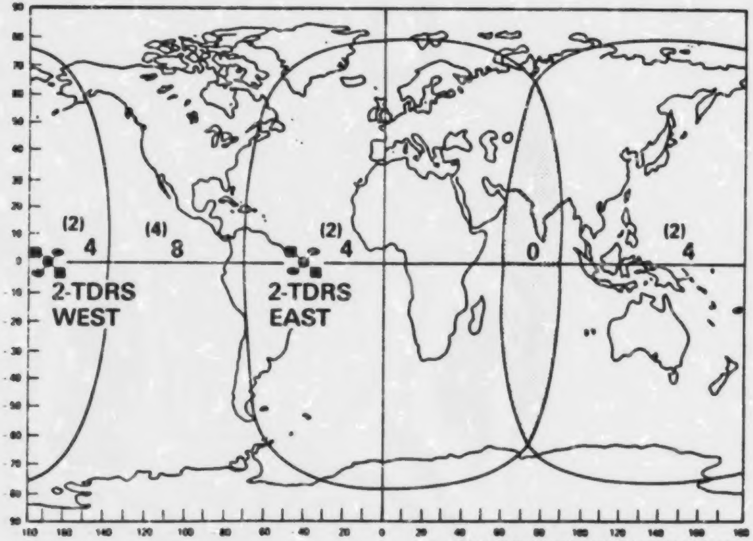
SPACE NETWORK

- ACHIEVE TDRSS OPERATIONAL CAPABILITY IN LATE 1986
- THE SIX SPACECRAFT IN THE CURRENT PROGRAM ARE PROJECTED TO PROVIDE FOR THREE IN ORBIT THROUGH 1994
- CONSTRUCT ADDITIONAL SPACECRAFT TO CONTINUE TDRSS ON-ORBIT CAPABILITY THROUGH THE 1990's
- AUGMENT SYSTEM TO MEET REQUIRMENTS OF EARLY 1990's
  - 300 Mb/s DATA RATE OF TDRS APPEARS ADEQUATE
  - INCREASED NUMBER OF WIDEBAND USERS REQUIRES MORE THAN THE FOUR SINGLE ACCESS LINKS AVAILABLE WITH TWO OPERATING TDRS's
  - ADDITIONAL GROUND STATION CAPABILITY REQUIRED
- PLAN TO OPERATE A FOUR, IN-ORBIT TDRS CONFIGURATION TO SUPPORT INCREASED WORKLOAD AFTER THE MID 1990's

NASA HQ TBB-681 (1)
REV. 8-11-86

FIGURE 12

SPACE SEGMENT CONTINUATION
(4 SATELLITE SA COVERAGE CONCEPT)


90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
(2)
4
(4)
8
(2)
4
0
(2)
4
2-TDRS
WEST
2-TDRS
EAST
180
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180

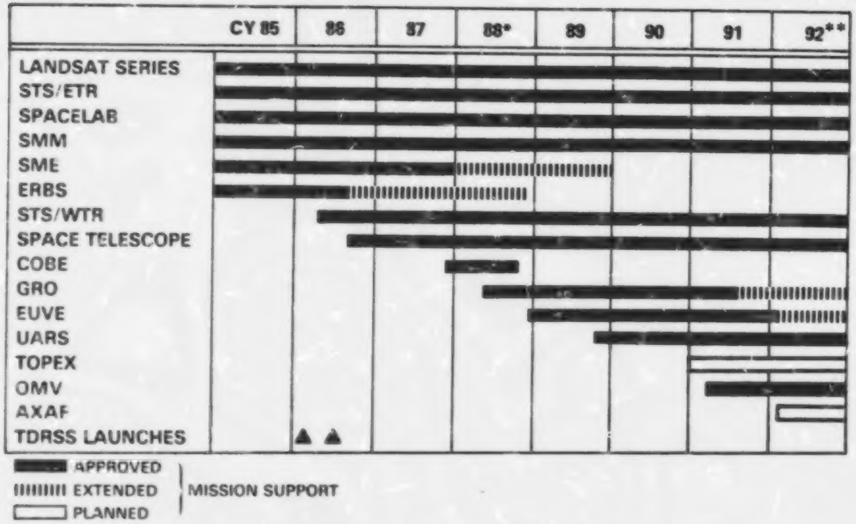
( ) PRESENT SYSTEM

TDRSS COVERAGE OF 200 NMI ALT USER SPACECRAFT
TDRS LOCATIONS 41W, 41W, 171W, 171W

NASA HQ TB5-7691(1)
REV 6 10 85

FIGURE 13

SPACE NETWORK
MAJOR MISSION SUPPORT PLANS



*SIMULTANEOUS SUPPORT OF TWO SHUTTLE MISSIONS STARTS 1988
**READINESS TO SUPPORT SPACE STATION BY 1992

NASA HQ 784 938A (1)
REV. 9-11-85

FIGURE 14

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PLANNING INTO THE 1990'S

COMMUNICATIONS

- CONTINUE TO UTILIZE COMMUNICATIONS SERVICES AND NEW DEVELOPMENTS IN THE PRIVATE SECTOR
- PLACE PSCN INTO OPERATION (PROGRAM SUPPORT COMMUNICATIONS NETWORK): AN INTEGRATED NETWORK FOR ADMINISTRATIVE COMMUNICATIONS SERVICES
- EXPAND OPERATIONAL COMMUNICATION CAPABILITIES
  - TDRSS DATA DISTRIBUTION LINKS TO INCREASE TO 300 Mb/S
  - USE FIBER OPTICS TRUNKS AND NEXT GENERATION COMMUNICATION SATELLITES

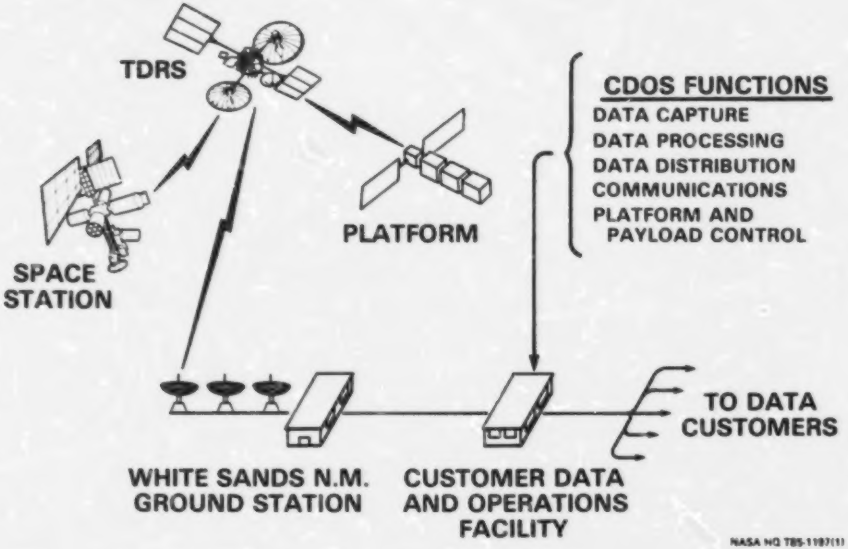
MISSION CONTROL AND DATA HANDLING

- PROVIDE CONTROL CENTER AND DATA PROCESSING CAPABILITIES FOR NEW MISSIONS: GRO, COBE, LEASECRAFT, UARS, SHUTTLE ATTACHED PAYLOADS
- PREPARE FOR SPACE STATION HIGH DATA RATES AND DYNAMIC, IN-ORBIT CHANGES IN PAYLOAD
- PROMOTE DATA SYSTEMS STANDARDS

NASA HQ T85-680 (1)
REV 9-11-85

FIGURE 15

CUSTOMER DATA AND OPERATIONS SYSTEM (CDOS) PLANNING FOR THE SPACE STATION ERA


TDRS
SPACE STATION
PLATFORM
WHITE SANDS N.M. GROUND STATION
CUSTOMER DATA AND OPERATIONS FACILITY
TO DATA CUSTOMERS

CDOS FUNCTIONS

- DATA CAPTURE
- DATA PROCESSING
- DATA DISTRIBUTION
- COMMUNICATIONS
- PLATFORM AND PAYLOAD CONTROL

NASA HQ TB5-1197(1)
9-11-85

FIGURE 16

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MAJOR T&DS PLANNING LONG RANGE

NASA HQ T86-[illegible] (1)
[illegible]

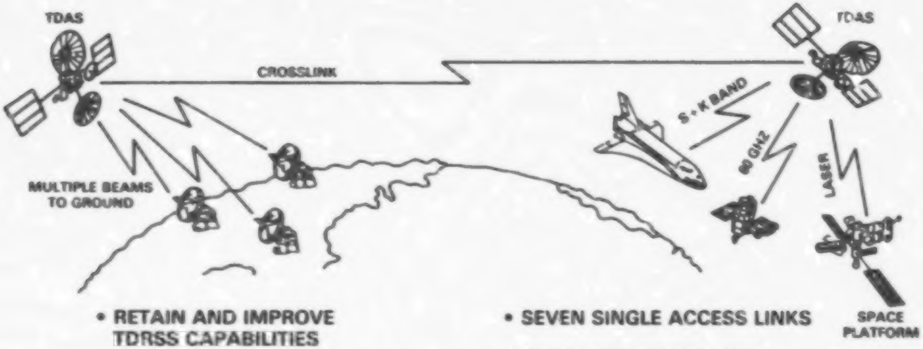
FIGURE 17

MAJOR T&DS PLANNING LONG RANGE

- SPACE NETWORK
  - REPLACE TDRS'S WITH A NEW "TRACKING AND DATA ACQUISITION SYSTEM" (TDAS)
- GROUND NETWORK
  - K-BAND LINK CAPABILITY FOR DEEP SPACE MISSIONS
    - INCREASE IN DATA RATE WITH TRADEOFF IN SPACECRAFT POWER, WEIGHT AND VOLUME

FIGURE 18

TRACKING AND DATA ACQUISITION SYSTEM (TDAS) FOR THE YEARS 2000⁺


TDAS
CROSSLINK
TDAS
MULTIPLE BEAMS TO GROUND
S + K BAND
60 GHZ
LASER
SPACE PLATFORM

- RETAIN AND IMPROVE TDRSS CAPABILITIES
- NO BLIND SPOTS
- UP TO NINE DIRECT LINKS TO GROUND
- SEVEN SINGLE ACCESS LINKS
- ONE LASER CROSS LINK, ONE Gb/s DATA RATE
- ONE LASER SPACE-TO-SPACE LINK, ONE Gb/s DATA RATE

NASA HQ T86-773 (1)
4 22 86

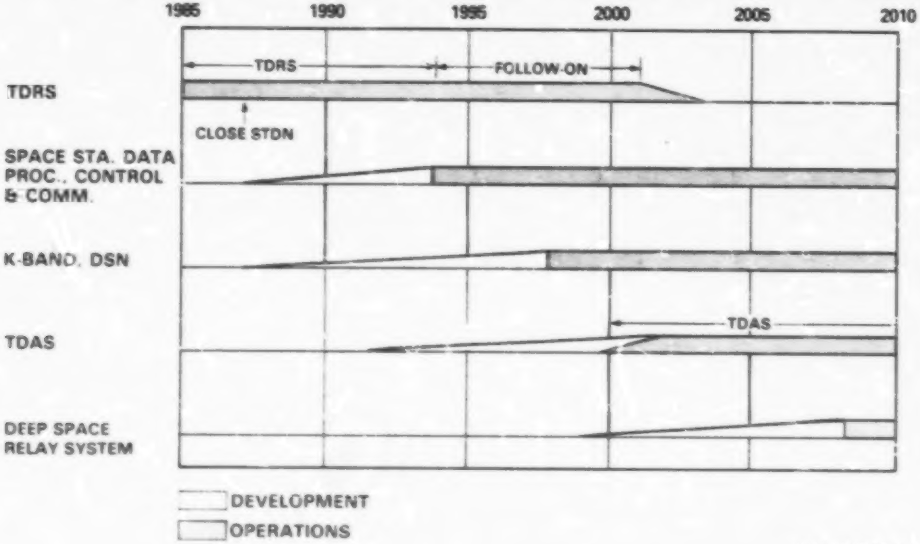
FIGURE 19

173

MAJOR T&DS PLANNING
LONG RANGE
(CONTINUED)

- OUTWARD LOOKING TDRS FOR DEEP SPACE MISSIONS
  - MICROWAVE (X, K-BAND) OR OPTICAL LINKS
  - INCREASE PERFORMANCE (X 10 TO X 100)
  - POSSIBLY COMBINE WITH TDAS OR GEO SPACE PLATFORM

PLANNING SCHEDULE
MAJOR FUTURE CAPABILITIES



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REV 9-11-85

FIGURE 21

Mr. **Nelson**. OK.

Anybody have any questions at this point?

[No response.]

Mr. **Nelson**. By the way, whoever was responsible for, once we had, I think it was, the pan that misfired—no, it was—what was the Air Force booster module on TDRSS?

Mr. **Aller**. The IUS.

Mr. **Nelson**. IUS. It misfired. Someone in NASA, or some number of people in NASA, were responsible for, through some extraordinary ingenuity, of getting the TDRSS, which you said is up there now working, into the proper orbit. Were they ever appropriately thanked and congratulated and recognized, for that matter?

Mr. **Aller**. We have recognized and thanked them, sir. I should say that you are absolutely correct, it was a magnificent effort. It was not, of course, just NASA. Our contractors, both the Spacecom Co. and TRW, were major contributors to accomplishing a 13,000-mile boost of that vehicle into geosynchronous, using the small thrusters on TDRS.

But it was a magnificent effort, and NASA has certainly recognized the people involved in that activity.

Mr. **Nelson**. That is somebody else then that I want us to recognize, because there again is the untold, as far as the world at large is concerned, heroics of folks in this agency that have made the impossible possible.

What was the reason that you had that extra fuel onboard TDRS which allowed you to boost it another 13,000 miles?

Mr. **Aller**. The extra fuel, the roughly 1,300 pounds of fuel we have on TDRS, is principally for the C-band operation, which was the original commercial package, one of the commercial packages on TDRS.

Recall, before the launch, that contract was converted so that it's a totally Government vehicle. That fuel reserve was all we had, for the C-band package on the TDRS. We planned to operate that—we're going to relocate that satellite into the spare location. We've had some problems with that satellite. It will become the spare when we get the other two up there.

We plan to operate that C-band. The lifetime of that operation will be limited to the fuel remaining, which is about 500 pounds at this point. But it is the fuel reserve to operate C-band for roughly a 10-year period, roughly 100 pounds a year that is stored on the vehicle for that purpose. So we will have at the most 3 or 4 years of C-band operation of that vehicle. The C-band operation is far less in priority to us in NASA than the S-band and K-band on the space use.

Mr. **Brown**. Mr. Chairman.

Mr. **Nelson**. Yes, sir?

Mr. **Brown**. I don't want to ask a question, but I wonder if I could ask Mr. Aller to provide me with any brief background documents or studies relating to the use of laser technology which you are looking forward to in the next generation. I am very much interested in what the development process is on that when we get to the point where we can utilize the megabit-per-second transmission capability.

I presume you have some studies?

Mr. Aller. No, sir. I have some studies. Most of our technology, we don't develop within my office; we utilize the technology that is developed elsewhere.

In this particular case, there is laser technology for space activities being developed generally. We have some internal operations that both Dr. Edelson and I are involved in of fairly small scale, principally focused at Goddard, looking at the very unique application of laser technology for space networks.

We are looking also to the future, and I believe we're still on a program to attempt to operate an experimental package in conjunction with a shuttle flight in the future to demonstrate the technology of being able to use space-to-space laser communications. Of course, what the laser technology does, it expands the bandwidth data rate that we can utilize.

Mr. Brown. Well, if you have something that would be suitable for congressional consumption, I would appreciate it if you could send something.

Mr. Aller. Certainly, sir. We will put that together.

[Information to be supplied follows:]

The Space Tracking and Data Systems Program has a laser communications study with the Goddard Space Flight Center which is underway for the Tracking and Data Acquisition System (TDAS)—planned as the 2nd generation TDRSS. This effort is expected to provide conceptual designs of three types of laser terminals, each with only minor differences, as follows:

a. The terminal on each TDAS spacecraft for establishing a communications link between them in geostationary orbit (cross link).

b. The terminal on the TDAS to transmit to and receive telemetry from low earth orbiting spacecraft.

c. The terminal on orbiting spacecraft using TDAS for relay to ground.

This study will aid in the determination of whether these links will use microwaves or optics. The optics approach is being considered because of the following potential advantages: transmitter/receiver "antennas" are typically 10 times smaller; multi-gigabit data rates (up to 2 Gb/s needed for TDAS cross link) are quite feasible; solid state, high efficiency transmitters look promising; and the high directivity of laser beams offer advantages of secure links with less interference and the option to reuse frequencies. However, we would need optical technology developments for TDAS for several key functions. These include solid state power amplifiers delivering one watt or more; receiving photo detectors for high data rates and four-quadrant acquisition and tracking; and demonstration of the ability to track and point such a system.

The microwave approach, on the other hand, has the advantage that its technology is more mature and consequently less risky to implement.

This optics study is small but vital for identifying the size, weight, cost and further technical efforts necessary for selecting and planning optical links for TDAS.

Also, the Aeronautics and Space Technology Program has several efforts underway to improve the performance of laser system components that can be applied to laser communications and may serve the needs of TDAS as well. This work is on the semiconductor laser diode power amplifier and the wideband optical detector.

The first centers on the GaAlAs (gallium aluminum arsenide) ternary compound and is directed at extending the lifetime of these devices to 10 years or more, while maintaining the radiative power levels and modulation bandwidths necessary for space communications. It is expected that power levels of 0.25 watts will be achieved in single element diodes, with power levels of 2–4 watts likely in a phase-locked array.

Optical detector research emphasizes a new type of photodiode which can potentially supply very high internal gain without the addition of degrading noises. Overall receiver sensitivity improvements of about 4x are anticipated.

With the successful completion of these activities, substantial system level benefits result which can be used to increase data rate, reduce size and weight, and increase performance margins.

Mr. Brown. Thank you.

Mr. **Nelson**. OK, now, Mr. Nysmith, you tell us how you're going to supply the quality of folks that Dr. Edelson and Mr. Aller and Mr. Beggs and everybody are going to require as we do all of these extraordinary things for the future.

STATEMENT OF C. ROBERT NYSMITH, ASSOCIATE ADMINISTRATOR FOR OFFICE OF MANAGEMENT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. **Nysmith**. OK, Mr. Chairman, I am glad you asked. [Laughter.]

First I want to thank you for your opening remark about the fact that the human resource is an essential and critical element. That's not commonly understood. Typically, what I am going to talk about today is thought of as the overhead which is there to be cut and slashed and reduced. What I intend to do today is to talk about the institutional planning that we do, not the planning itself, but where we are trying to go.

I am going to have to do some stage-setting for you in some of the areas so you will understand some of the challenges we face. I don't want to paint this as a bleak picture, because I also think there is an opportunity for us that I want to bring up right at the end.

Now, we don't do institutional planning, obviously, for its own sake. It is there to do the programs.

Could I have the first chart?

[Figure A.]

It is done as a participative approach with the institutional program associate administrators and the centers. But this is really what we view the institution for, is to maintain the agency's capability in those three areas.

I am going to say just a few words about each of those areas, more about the people than the others, because that is right now where some of our major challenges are. But it is there to do the programs. It's not there to be a center or just to be an institution, but to do the programs.

OK. Let me give a little background on the people and kind of where we are. The first chart gives a bit of a historical depiction of our manpower within the civil service in terms of people. Back in the Apollo days we had like 31,000 civil servants. We currently have about 22,000 civil servants.

There are two messages there. One message is that we have come down about 33 percent. That is quite an uncommon occurrence in the Federal Government. But another point on that chart is that as we have done this, we've taken it out of the administrative and support areas. We have tried to maintain to the maximum extent possible our scientists and engineering capability. And that's what the bottom line is.

You can see that the relative percentage of S&E's to the total work force has increased over time. We have taken some reduction, obviously, but not the same percentage as across the board. Today we're a little over half of the almost 22,000 civil servants in NASA are S&E's. There is no other Government agency that comes close to that. And we've made a conscious decision and effort to do that.

It creates some problems for us.

Let me have the next chart.

[Figure 1.]

I want to take a quick look at the age problem I had. Now, this is the 1975 data. I am only showing it because I am going to show you current data on the next chart. This is just to kind of orient you with what our average age is.

In 1975, you can see the peak age was about 40, in the 40-to-44 range. That's what that business is on the bottom. On the left is the percent of all employees. And that's a reasonable plot; you have to have an average age somewhere. That's pretty well at the journeyman level, really high-performing, let's call them the Dr. Farquahar and other age group who are really at their peak.

Could I have the next chart?

[Figure 2.]

This shows the comparison of 1975 and 1984. Our average age has marched ahead in time. In 10 years our peak average age has moved out to the 45-to-49-or-50 age group. So what does that tell you? We have an aged and aging work force.

As we look to the future, we see a couple of problems coming up. One, that large group of people is getting very close to retirement, and even worse, if some changes are made in this system, they might decide to exit stage left all at once. That can be a problem for us.

But if you also look at that curve, down at the bottom on the dashed curve you see a second hump at the 25-to-29 age. Now, that is opportunity. I mean, that's what you would like to see. We are, because we have stabilized now the civil service work force, able to hire fresh-outs, and we've had significant hiring of fresh-out S&E's over the past couple of years.

Mr. NELSON. Now, that's typical of society at large, basically.

Mr. NYSMITH. True, True; I think that you're right.

Now, for us, that creates a problem for us, though, because it's not sufficient for us that we just have S&E's. Because of the kind of work we do and that Burt Edelson has talked about and the other AA's, requires people right out at the leading edge, and it just takes time for them to mature into the system. We're running out of time. But we have the aging work force and the fresh-outs.

One other point that is not commonly understood is on the next chart.

[Figure 3.]

And I am not going to go through this at all, and the only purpose of this, though, is to point out that whereas about 15 years ago one could consider the shelf life of, let's say, the technology that a graduating scientist or engineer had was about 10 years, today it's about 5 years.

The technologies are advancing so fast, they become extremely complex and multidisciplinary, that there is a great need to keep your S&E's current. What this is gettting at is that this is a problem that has suddenly come up—well, not suddenly, but is worse now than it used to be.

If you just take the field of materials and march across, starting in 1975 with a field that's fairly broad, metals, a person could graduate and pursue a career in that. Then, today, you know, with composite ceramics, you've narrowed the field down, and expertise gets much more detailed levels. And now we're looking at super-alloys and super-composites.

That is to say that some of that work force we have which graduated 20 years ago has to work very hard to stay current in the modern area, and we need that kind of currency.

Now, one other point is on the next chart, which is: Attracting new people.

[Figure 4.]

This is a comparison of graduates with B.S. degrees on the left-hand side and graduates with M.S. degrees on the right-hand side. Now, this is NASA-wide, and it's comparable to industry. The problems are better or worse from center to center, and this is just an average.

It shows that there is about a $3,000 difference in offering salary for the people we're competing for. Now, that's not to say we're not getting good people. We are, but we just have to work very hard for it. The NASA Program attracts good people, so that, thank goodness, is a great help to us. But we have to work hard to keep this.

Unfortunately, the band is widening, and so that's the challenge.

Now, let me say what we're going to be trying to do about that. If you take a look at the problem I mentioned of disciplinary changes, of people having to become current, and the fact that we have a large number of people who are going to be leaving, we have to have that second bump in the curve ready to come in. We are greatly expanding our development and training activity to ensure we're ready.

So that's one activity we're doing. We're focusing very strongly, and will be focusing, on what we call productivity-enhancing activities; that is, employees' suggestions, getting people together to develop in a team working relationship, to make better use of the people we have.

We are putting together right now a proposal under the Civil Service Reform Act on what we call a personnel demonstration program, which I imagine you are familiar with, which would allow us to become more competitive on starting salaries and other such things as that. It hasn't been accepted. We haven't proposed it yet, but we're working on that to try to compete with the outside.

Another thing is we're putting a significant effort on trying to enlarge our pool of minorities and women, primarily because that's a pool that we really do need to tap, especially when we're after the best people out there. So we're trying to expand that. So our planning over the next 5 to 10 years is really oriented toward that area of people.

Let me say a few words about facilities.

[Figure 5.]

I would like to show just very briefly a history chart of what we spend in NASA on construction of facilities. Now you can see in the 1963 timeframe, which was the big buildup for Apollo, that we spent a very, very large amount of money in that one short period of time. But that's very uncommon.

More typically—and this is shown both in real-year dollars, which is the solid curve, and what it really was that year; the dashed curve is corrected for inflation—but the point here is that we operate along with highs and lows, but generally at about a $200 million a year level in construction of facilities.

Last year, or this year, the C of F budget of NASA is at $150 million. And if you just kind of draw a line in your mind's eye where we are, we're below where we traditionally have been in the past.

And that's given us a problem. We have trouble maintaining facilities, we have trouble repairing them, and these days we build very few new facilities. We do modernizing, upgrading, improvements as new requirements come along.

We rarely build a brand-new facility. Occasionally one will come up, but that requires a very, very strong program requirement and, obviously, your support.

So that's just to show you about the amount of money we spend. If you take a look at what it's worth to us, if you add up the book value that we've spent over time—and this does include what we've taken out of commission—there's about a billion dollars' worth of facilities that we've taken out of commission.

We have spent about $3.4 billion over time. Replacement value today is about $11 billion. We spend about $150 million to maintain that and improve it, which is below the norm of almost any company or industry. And that is what I say gives us a problem.

Now, what we've done over the past couple of years, in the past our facilities have been keyed to developing or putting in the kind of facilities to develop the space shuttle and to keep the aeronautics program viable across the board. As we look at what we're going to be doing in the future, we intend to continue to put into place those R&D programs to support the aeronautics and space technology programs.

We will be trying to provide for space station development, and we will be trying to now provide for space shuttle operations as compared to development, because that still requires some construction of facilities.

We will also be keying to complying with environmental objectives or trying to meet the environmental compliance legislation, improving energy efficiency and productivity, and continuing support for what we call the minor programs, that is, the repairs. We spend about $60 million a year on minor programs. Those are where things break or need repairing, almost unplanned.

That is spread throughout the Centers and is kind of what is considered by the Center Directors as the biggest problem they have, is that they're constantly under the constraint of not being able to do what they need to do at that level.

OK, now the next chart.

[Figure 6.]

Just a few words about our equipment. This is everything else. We have about $4 billion worth of equipment, and that includes a lot of things. But again, you can see that that number has remained at least slowly going up but has not had very, very large excursions.

Let me show the next chart to show you what's in that package.

[Figure 7.]

It does have—it includes the shuttle—let me say, the shuttles are in that package under launch vehicles.

[Figure 8.]

Now, this is a 1984 chart, so that number only includes two orbiters instead of what we now have, so the number has obviously gone up in 1985.

It includes ADP equipment, lab equipment, the support aircraft, and the research aircraft, electronic equipment, and all of that business. The point of this chart is that the institutional funding that we get supports all of that, and it is critical and essential to the conduct of the program.

It's something that we can't seem to convince anybody that it really is that critical, but one can nickel-and-dime this to death, and it is a very, very large demotivating effect on the people out at the Centers as they find they can't get what they need or they have to work with second-rate equipment.

We have laboratory equipment that is 12 years old, and the technology is moving so much faster than that, that we're using vacuum tube equipment in some places, you know, which just gives you an idea. And it's very, very difficult, though, to put this in a priority of an R&D program to make some of the changes that we have to make.

So our plan, though—never giving up—is to try to maintain that equipment at the level we need to do that.

Now, if you summarize our emphasis in that area for those three, we clearly have a changing work force that we have to manage. And we're working at that.

I mentioned the training and those items like that we're working on. We have to maintain these facilities. They are the lifeblood of how we do our work at the Centers. They're expensive, but they need the capability they offer. And we need to maintain a level of inhouse equipment that lets our people have the right kind of things to work with.

May I have the last chart?

[Figure 9.]

Now, I think there is a real opportunity coming up, and this is the opportunity that, even though we've had these challenges, we have coming together this new wave of scientists and engineers, that second wave on the chart. And as the other people that I showed as the first big bulge retire, we are going to have significant opportunity to hire.

The key is in being ready, is in having these young people ready to move in, and they should be coming in just about the time that we are embarked on a major new activity—that is, the space station—so they will have a focused goal.

We currently have a world-class facility in terms of our institutions and of our equipment if we can maintain that. So when 1990 gets here and comes in that space station, 1992 or whatever it is, I think these things should come together.

But the key is we have to do it to be ready for that to happen, and that's what our plan is keyed toward, ensuring that we are on that road.

[Statement of Mr. Nysmith follows:]

INSTITUTIONAL MANAGEMENT ROLE

MAINTAIN THE AGENCY'S CAPABILITY...ITS

- PEOPLE
- FACILITIES
- EQUIPMENT

...TO SUPPORT THE NASA SPACE PROGRAMS...

FIG. A

183

NASA CIVIL SERVICE WORK FORCE
TOTAL POPULATION/SCIENCE & ENGINEERS

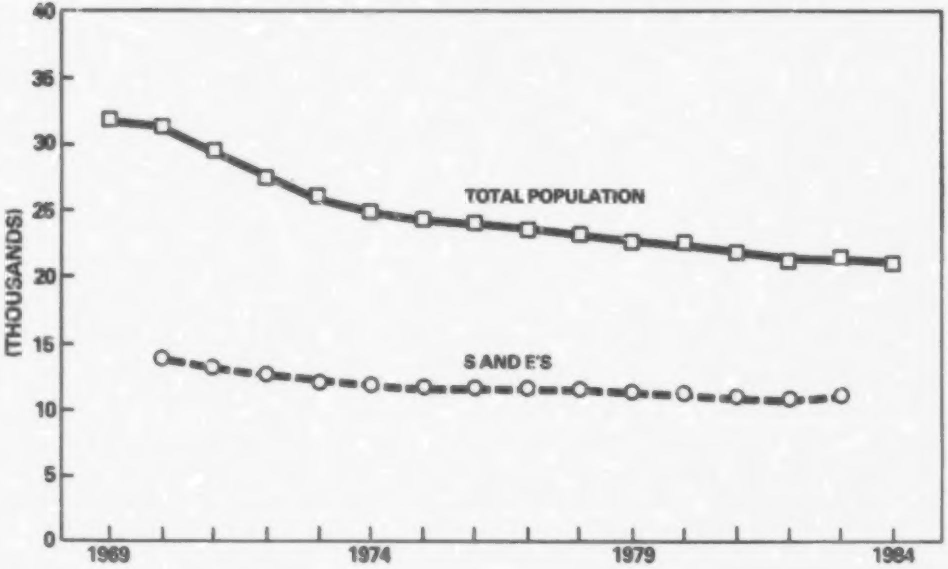


FIG. 1

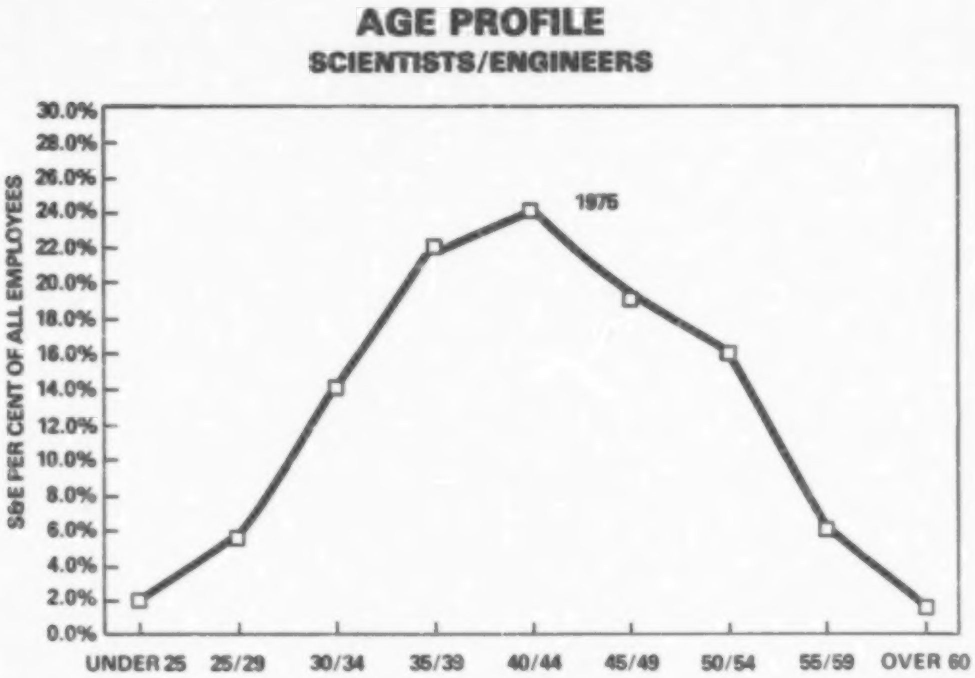

AGE PROFILE
SCIENTISTS/ENGINEERS
S&E PER CENT OF ALL EMPLOYEES
30.0%
28.0%
26.0%
24.0%
22.0%
20.0%
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
1975
UNDER 25
25/29
30/34
35/39
40/44
45/49
50/54
55/59
OVER 60

FIG. 2

AGE PROFILE

SCIENTISTS/ENGINEERS

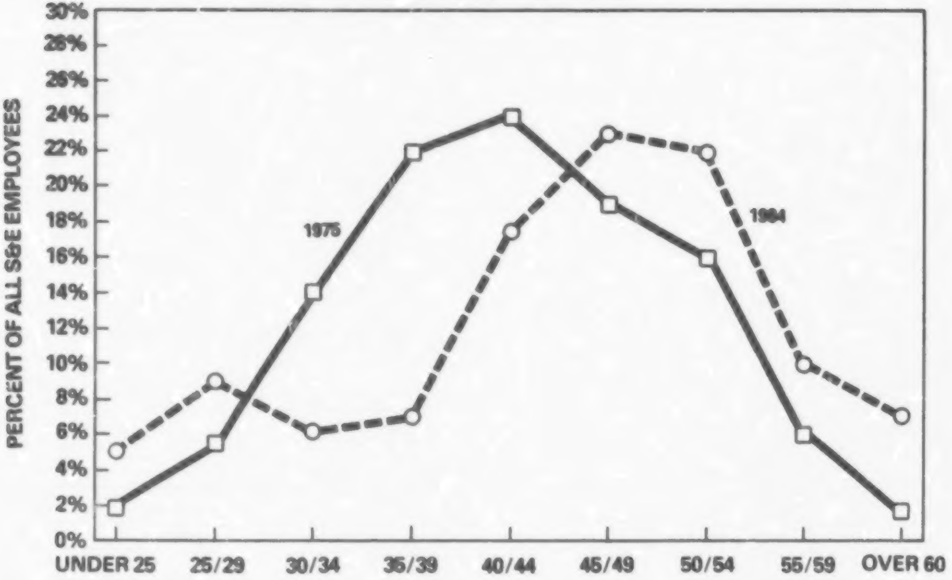


FIG. 3

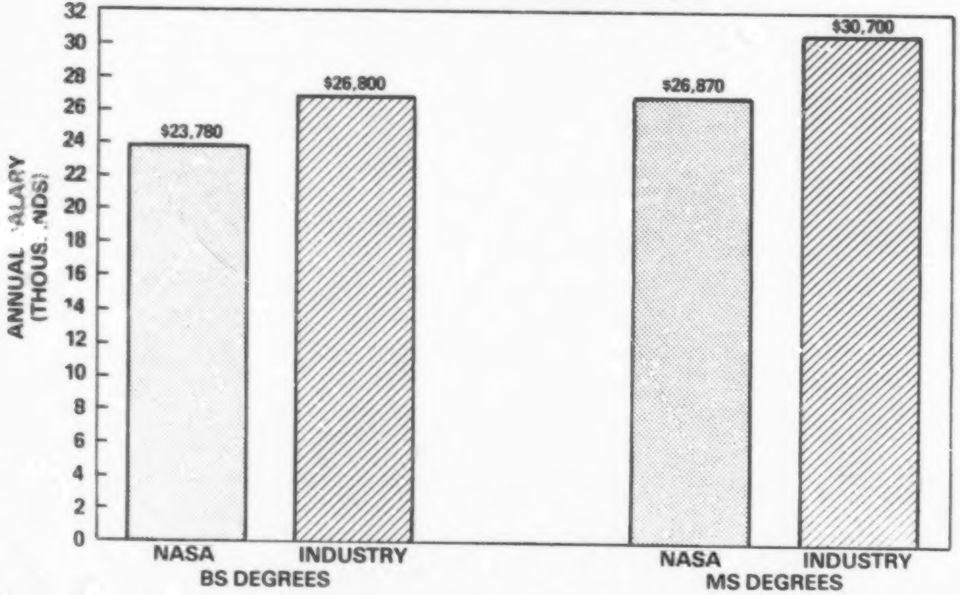
DISCIPLINES REQUIRED

COMPLEXITY + →

MULTIDISCIPLINARY + →

DISCIPLINE	1975	1985	1995
PROPULSION	CONVENTIONAL AIRBREATHING & CONVENTIONAL ROCKET	LIFE AND PERFORMANCE	HYPERSONIC FLOWS AND COMPUTATIONAL METHODS
MATERIALS	METALS	COMPOSITES & CERAMICS	SUPERALLOYS & SUPERCOMPOSITES
AERODYNAMICS	FLOWFIELD UNDERSTANDING	COMPUTATIONAL METHODS	MICROFLOWFIELD CONTROL
CONTROL	FLY-BY-WIRE	RELIABILITY AND FAULT TOLERANCE	FULLY INTEGRATED AND RECONFIGURABLE CONTROL
ELECTRONICS	NAVIGATION, GUIDANCE + CONTROL	MICROELECTRONICS	HIGH ENERGY PHYSICS & SUBATOMIC THEORY
COMPUTER SCIENCES	FUNDAMENTAL UNDERSTANDING	ROBUST SOFTWARE	ARTIFICIAL INTELLIGENCE ROBOTICS
STRUCTURES	STRUCTURAL ANALYSIS	CONTROL/ STRUCTURE INTERACTIONS	DISTRIBUTED, ADAPTIVE CONTROL OF FLEXIBLE STRUCTURES

FIG. 4



NASA/INDUSTRY SALARY OFFER COMPARISON
ENTRY LEVEL ENGINEERS—1985

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FIG. 5

NASA FACILITIES CONSTRUCTION
EXPRESSED IN REAL & CURRENT YEAR $

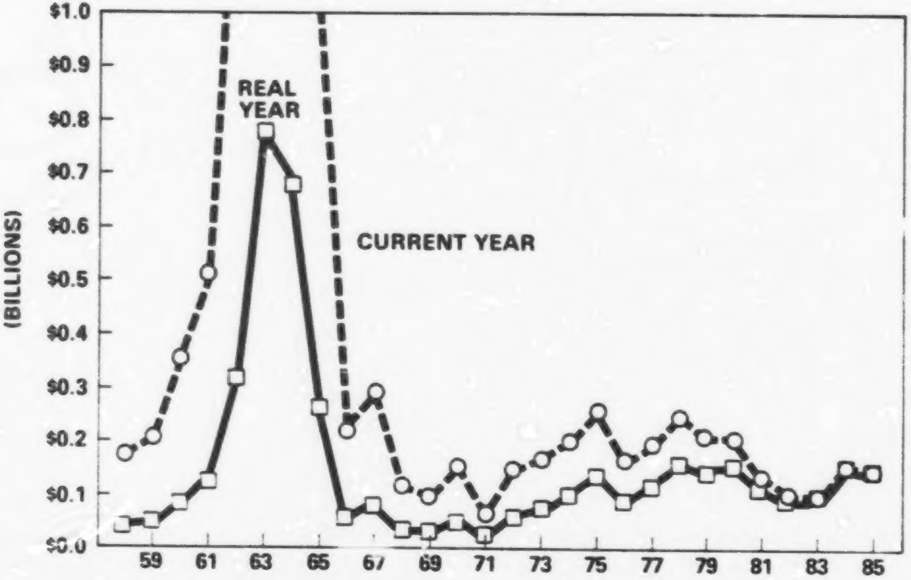

FIG. 6

NASA EQUIPMENT HOLDINGS

EXPRESSED IN REAL AND CURRENT YEAR $

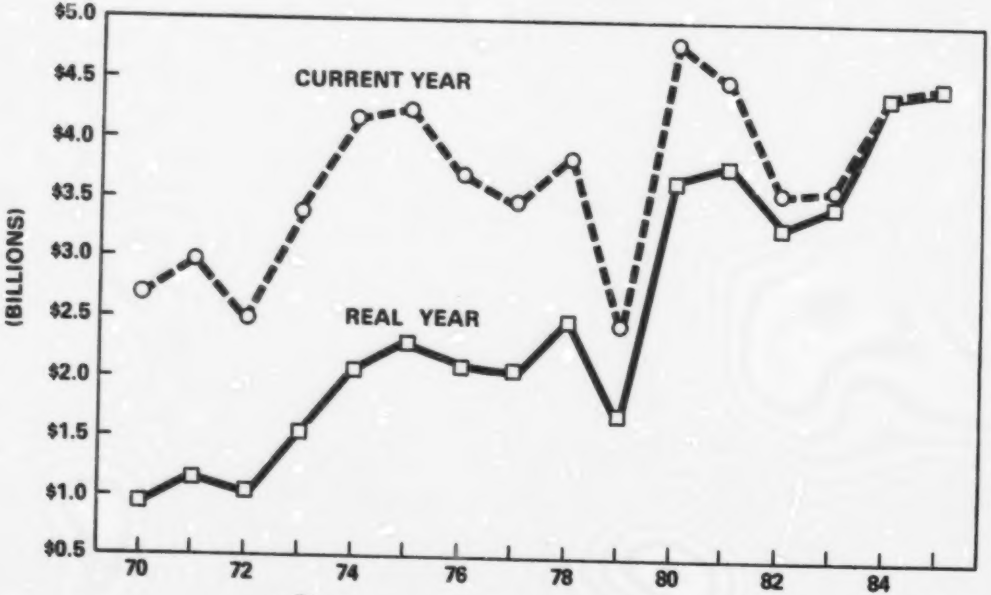

FIG. 7

INSTALLATION-HELD CAPITAL EQUIPMENT

FY 1984

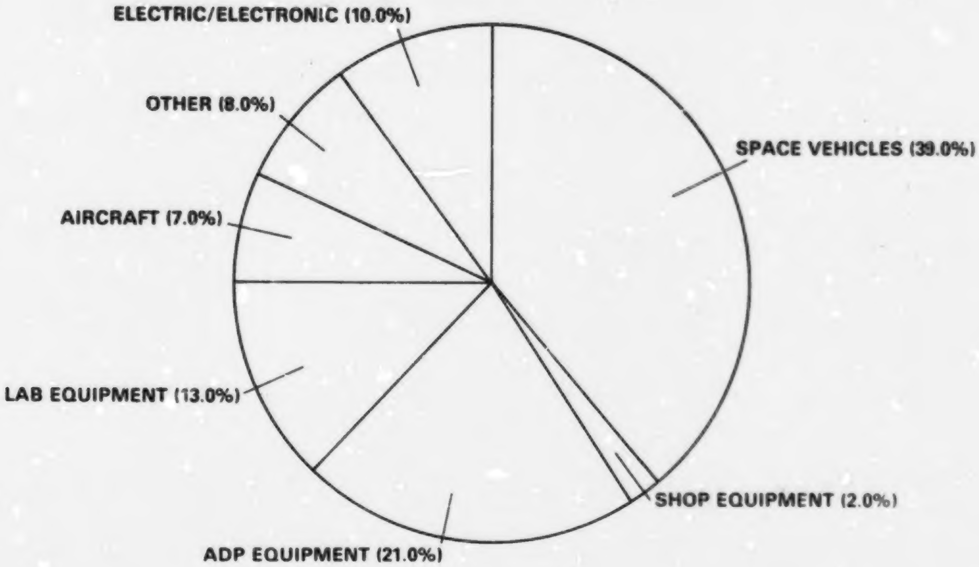

FIG. 8

A REAL OPPORTUNITY TO RENEW NASA

- A NEW WAVE OF YOUNG SCIENTISTS AND ENGINEERS
- A NATIONAL GOAL TO ACHIEVE AN OPERATIONAL SPACE STATION
- AN INSTITUTIONAL BASELINE OF WORLD CLASS FACILITIES AND EQUIPMENT

FIG. 9

Mr. **Nelson**. To get the big picture, we need to see a chart that not only would have your civil service employees at NASA but also your contractor employees.

Mr. **Nysmith**. Right.

Mr. **Nelson**. Do you have such a chart?

Mr. **Nysmith**. Yes; we can provide that for you.

We have about, onsite at the Centers, just about the same number of support contractors as we have civil service, about 22,000. That's onsite. We support about 115,000 contractors out doing R&D.

But I can give you that information.

Mr. **Nelson**. All right. And that same kind of analysis of that work force, which is very much a part of the NASA team.

Mr. **Nysmith**. Yes, it is.

Mr. **Nelson**. I would like to see that, to see if we see any kind of blips, any unusual things, are the contractors doing the same kind of thing that you're doing, are they planning ahead, do they have that bulge in the 25-to-29 group? I assume they do.

Mr. **Nysmith**. Yes; OK.

Mr. **Nelson**. But to see, do they?

Mr. **Nysmith**. That's a good question.

[Information to be supplied follows:]

The heart of the NASA institution, its scientific and engineering employees, are for the most part Civil Servants. As a result, the contractor workforce provides a broad range of personnel including large numbers of highly skilled technicians and relatively few scientists and engineers.

NASA contrator activities fall primarily within "support" and "manufacturing" classifications, representing, in the one case, labor intensive, level of effort activities, and in the other, design, development, manufacturing, and testing activities related to the production of hardware. Thus, the issues critical to NASA management concerning its S&E workforce do not apply in the same way and to the same extent to the NASA contractor workforce.

Moreover, the burden of management responsibility for providing a qualified staff would impact on the contractor's capability to enjoy continued business success with NASA. For this reason, and to remain in compliance with the Government's efforts in keeping reporting requirements to a minimum, there is little demographic data available on the NASA contractor staff.

The table, below, shows the comparative number of NASA civil servants and contract employees for 1984 and 1985, and projected for 1986:

NASA CIVILIAN AND CONTRACTOR WORK FORCE—NUMBER OF EMPLOYEES

Category	1984	1985	1986
Civil Service (all categories)	22,080	22,000	21,800
Contractor (mfg.)	59,700	56,800	53,500
Contractor (support)	80,000	76,300	79,900
Total	161,780	155,100	155,200

Consistently representing about 84% of the total NASA work force, this contract effort is crucial to the success of NASA's programs and will continue to be carefully monitored.

Mr. **Nelson**. Mr. Brown.

Mr. **Brown**. Mr. Chairman, if you will request an opportunity to submit questions in writing in response to staff questions?

Mr. **Nelson**. Certainly.

Mr. **Brown**. I will defer my questions so that the others may inquire.

Mr. **Nelson**. Certainly. But help yourself, too. I mean, we've got time here, and we're not having to jump up and race to go vote. So, delightfully, we can proceed.

Mr. **Brown**. But we might have to at any moment.

Mr. **Nelson**. True.

Mrs. Meyers.

Mrs. **Meyers**. I have no questions—I can't talk. [Laughter.]

Mr. **Nelson**. Well, bless you.

Mr. Monson.

Mr. **Monson**. Just to follow up on what the chairman was pursuing there with the contract employees, is there a distinction there between people in that category and consultants that you might be using, or would it be helpful to us to see a chart showing consultants as well?

Mr. **Nysmith**. Well, throughout the agency we have, in fact, very few consultants. We would be happy to provide the numbers to you. Those are, you know, because of various requirements laid upon the agency, all have to be approved at NASA headquarters, and so it is very carefully scrutinized and limited.

But we would be glad to provide those numbers.

Mr. **Munson**. Those numbers haven't increased as the employees have decreased?

Mr. **Nysmith**. No; I don't believe those numbers have. I will say that if one looks across the agency over the time period from 1963—no, not 1963; whatever the chart was I showed that showed the coming down of the NASA people—the support contractors onsite have risen in that same time period. That is because what we've done, as I mentioned, was maintained the scientists and engineering work force as high as we could and contracted out a lot of the, let's say, less technically oriented things.

We were well ahead of A-76—even before it got invented—that is, the contracting out of those things that can be done better by industry. Most of the janitorial services—and I don't mean to paint those pictures all that way—we have engineering design under contract, support contract, at many of the Centers because it's something you can give them a job to do, tell them what it is, and they can apply architectural skills to that and do a better job than we can do. And we have attempted then to devote our in-house R&D people to doing in-house R&D.

Mr. **Aller**. If I could expand on that just a moment. One of the things we have done in NASA over the years—and we saw it take place down here at the cape a year ago, roughly, when we consolidated the shuttle processing contract into a single contract, replacing some of the civil servant activities at the cape at Houston—coming up in January we just consolidated a major support activity that basically will do the flight planning, flight control, flight support from the Houston activity.

We have done a mission contracting kind of thing. We've done some of that also in the networks area with our contractors; for instance, the White Sands facility is totally contractor-operated. Our networks are totally contractor-operated, or foreign contractor-operated.

So we have been able, through that technique, to maintain our R&D people in the development activities and in the research activities, and when we have reached an area of activity that can be turned over more completely to a contractor, we have done that. And I think we will be doing more of that in the future.

Mrs. **Meyers**. Mr. Chairman.

Mr. **Nelson**. Yes, Mrs. Meyers.

Mrs. **Meyers**. May I ask one question?

Mr. **Nelson**. Certainly.

Mrs. **Meyers**. This question arises after talking to some people who have a firm at home. Do you utilize more scientists or engineers?

Mr. **Nysmith**. Throughout the agency?

Mrs. **Meyers**. Yes.

Mr. **Nysmith**. Well, I think we—and I will say, "I think," because I don't remember the numbers—probably significantly more engineers. The science people are almost all supportive of Burt's activities.

Probably the largest cadre of people, if one wanted to classify them, is in in-house support of the Office of Aeronautics and Space Technology because that is a very in-house facility, you know, aeronautics and space technology-oriented activity.

As I recall, the number is about 5,000 people more or less are kind of working in the OAST programs. That's a very large number in comparison to the dollars that are supported by the program. That's because much of it uses the in-house program.

Now, the scientists, most of them are actually performing science missions in support of Dr. Edelson's programs. It's a bit different, I think, and perhaps you had better have Burt say a few words about how they operate, but they're a bit different than the other engineers who are typically tightly interweaved with an industry group that is working with them, with the NASA people and of doing one part of the action, and then under contract to industry, with industry doing another part.

Mrs. **Meyers**. Do you have any difficulty getting the numbers that you need in terms of engineers?

Mr. **Nysmith**. Not the numbers. And I won't even say the quality, because we still do attract a very high quality. The average grade-point average NASA-wide that we hire is like 3.2, which in grade-point average obviously is not the bottom line, but we find that the creativity of the people we've been getting is very high.

As a matter of fact, the word is that the people we're getting now are among the brightest that we've had. And you hear that from the Center people, the Division Directors at the working level. They're very impressed by them.

But we have to work pretty hard at it. We find, for instance, we don't send personnel people out to do recruiting, we send project engineers. I mean, they go out and they're one-to-one. You may recall last year or the year before, Dr. Mark went out and recruited.

I think, right now, what is selling is, in large part, again the NASA mission. People are excited by it, and some of the things that Burt talks about, and Phil Culbertson with the space station.

they can kind of see it as a renaissance of the space spirit, so to speak.

Mrs. **Meyers**. Thank you.

Mr. **Nelson**. Excuse me, Mrs. Meyers.

Are any of you having a morale problem, the fact that we're going to have a freeze on salaries?

Mr. **Nysmith**. There's a morale problem. I think a freeze on salaries is not by itself the big problem, it is a bit of the negative rhetoric about the Federal employee. NASA tends to overcome that because most NASA employees, very honestly, don't think of themselves as Federal employees.

Mr. **Nelson**. That's right, yes; you're in the middle of a razzle-dazzle activity.

Mr. **Nysmith**. Yes; "The Federal employee is that guy. It's not us, we're NASA."

Mr. **Nelson**. Yes; that's good.

Excuse me, Mrs. Meyers.

Mrs. **Meyers**. That's all right.

Do you think the educational system is adjusting to the changing needs as fast as they should? For instance, I know that in my State, I think we have had a hard time attracting science teachers. And if kids don't get started in high school, then they don't go on in college.

Do you have any comments on that?

Mr. **Nysmith**. Yes. I probably shouldn't, but I will say, that the answer to your question is, "No." I think that is a significant problem. I don't know how to solve the problem.

One of the things that we are looking into is actually trying to encourage our engineers and scientists at the Centers is to go teach part-time at some of the local universities. But that only solves an immediate problem. I think it is a big problem.

Clearly, the best—I shouldn't say that is the best—but clearly, a scientific discipline, a teacher who is teaching in a technical area typically has to turn down a pretty good offer from the outside world to stay teaching. So the competition for that person is very, very high. That's the problem. I don't know how to get around that.

Mrs. **Meyers**. There are those who say that it is the inability to attract science teachers to high school education is serious enough that there should be an infusion of Federal money into schools as there was back at the time of Sputnik when everybody became alarmed at how we had fallen behind in science at an early age with our kids. So we had an infusion of money into the school system.

Do you think we are at that point again? Maybe that's not a fair question to ask you, but you know, I have been really concerned about it as I have watched it develop over about the last 5 years.

Mr. **Nysmith**. Well, I would answer the question by saying that I think the time has come where we, the country, has to do something. Whether that's the answer, I don't know. I would like to hope that there are more innovative solutions than pouring money on it. I have to admit, as I sit here, I don't know what those innovative solutions are, but clearly, that is a big problem today.

Mr. **Nelson**. You know, you all might, as a followup to Mrs. Meyers, want to see if there is any way that you can quantify how, as a result of the teacher-in-space, it reinvigorates and rekindles an interest of people to go into the teaching profession. I am not sure how you do it, but somebody in NASA ought to be thinking about it, because NASA ought to get part of the credit.

Indeed, there is a resurgence and renewed interest among the teaching profession which, thank the good Lord, is happening across the country. And this experience of a classroom in space ought certainly to add to that.

But in order for NASA to get credit for part of it, figure out how you might measure that, if you can. I am not sure you can.

Anybody else?

Mrs. **Meyers**. Mr. Chairman.

Mr. **Nelson**. Yes, ma'am.

Mrs. **Meyers**. Also, I would like any thoughts that you have as far as to how to attract people back into the teaching profession. I don't know, it may be just a matter of money, because scientists and engineers both are in so much demand that they come in and make significantly more money outside of the classroom than they can in the classroom. So it may be just a matter of money.

But do any of the NASA scientists and engineers do any part-time teaching?

Mr. **Nysmith**. Yes; they do. That's one of the points I tried to make is that we're trying to now encourage them to do more, such as giving them administrative leave, which is to say, let them do it on working time, encourage them to do it, make it part of—you know, one of the ways to do it is to incentivize them that those people who actually teach get a reward for it from NASA. Today, it would be difficult for somebody working on one of Burt's exciting programs right in the forefront of a science project for him to then decide to go teach and take the time out of the project.

It would be difficult for him to decide to do that, but he could, and would, I think, if encouraged to do that and share what he's learning with the young people. That's the kind of thinking we're putting into it.

But again, you only get a few local universities involved in that. That's a plus, but you don't impact much.

Mr. **Edelson**. If I could add a point on that that we're most concerned about is quality and numbers of teachers that are available at the junior high school and the high school level.

Mrs. **Meyers**. Right; that's what my concern is.

Mr. **Edelson**. The National Academy of Sciences' study has recently underlined that. As Mr. Nysmith has said, we get good quality people out of the U.S. universities and graduate schools. They are, particularly the science and engineering graduate schools, the best in he world, and that's why they're flooded with people from other countries nowadays.

But the real problem is the lack of qualified teachers who are available in the junior high level and high school level.

Mrs. **Meyers**. Right.

Mr. **Edelson**. To the point where many teachers who are assigned to teach science, rather than helping, are hurting, since many of them find science and mathematics distasteful and impart to the students that opinion of science and engineering in general. That's a major problem that we see all around, and I think probably we've seen it with our own children as they go through the school system. And I believe it's getting worse.

Mr. **Nelson**. Oh, really? Instead of changing for the better?

Mr. **Edelson**. Yes; at the junior high school and high school level. You know, in certain States, there's been a lot of publicity about this; for example, the State of Georgia is recruiting for science teachers in Germany.

Mrs. **Meyers**. Yes; that is really a problem. I think this is why some have suggested that maybe it is enough of a nationwide problem, considering the need for scientists, that maybe a short-term infusion of Federal money directed just toward that. And no one likes to think about putting money into new programs now. In fact, we're going just the other way to try to control the deficit. But this I do think is a nationwide problem. I don't think it's just Kansas that's having this problem.

Mr. **Edelson**. We have one interesting, let me call it, an experiment or initiative under way at the Jet Propulsion Laboratory. We've established in Pasadena, in conjunction with the school system of Greater Los Angeles, a teacher learning center, a science learning center, the purpose of which is to teach teachers to teach science.

Mrs. **Meyers**. Right.

Mr. **Edelson**. And the subjects of whom are generally not science teachers, but English and social studies teachers and so on who are recruited to teach science. At this learning center at JPL—which I would certainly invite any of the members to visit or maybe the staff people would like to, to understand what we're doing out there—NASA, JPL, Cal-Tech, kind of together, are working with the school system out there to promote science teaching at the local level.

We have invited the Department of Education to send representatives out there, and also the National Science Foundation. The National Science Foundation particularly is interested in and are wondering whether that would be a good pilot system to establish around the country.

Although that's not my field, teaching at that level—I personally am very stimulated with it, and a visit to that learning center would be worthwhile.

Mr. **Nysmith**. Ideas like that are some of the ones I was thinking about when I said "some innovative ideas rather than just perhaps pouring money on it."

Mr. **Nelson**. Mr. Smith, and Mr. Slaughter.

Mr. **Smith**. I have no questions, Mr. Chairman.

Mr. **Slaughter**. Thank you, Mr. Chairman.

Dr. Edelson, what is the situation in the space science field contractors and so forth with respect to engineering technicians, those that usually have post-high school educational training of 1 or 2 years?

Mr. **Edelson**. Well, it's kind of hard to generalize on that. Mr. Nysmith pointed out that more and more, NASA is going to the use of support contractors rather than civil service people to operate facilities and to do processing, and so on.

In general, insofar as possible, we use contractors to do engineering technologists' work. For example, we will turn over a machine shop or a processing facility or the operation of a computer facility where you have what you might call technicians rather than graduate engineers.

If your question has to do with the availability of them, that really depends upon location. Now, one of the things that Mr. Nysmith might have mentioned is there is a big difference about NASA's ability to recruit, hire, maintain, and work with people, let's say, at Huntsville, AL, or the Cocoa Beach area, let's say, in Florida, than there is in the San Francisco area, such as our Ames Research Center.

In Huntsville, for example, it's a premier establishment. Bob probably has got a lot of figures on this. But we are able to get the cream of the technical capability at the technician level, at the engineering and scientist level, from all around that whole area, whereas in San Francisco, right in Silicon Valley, poor Bill Ballhaus is out there trying to recruit against an enormous differential in pay scale.

Mr. NYSMITH. Plus, if he's successful, then the rest of the industry around him looks at Ames as a training center, and in 2 or 3 years he can't keep them. So if he can hire them in the first place, he knows he's going to lose them soon.

Mr. SLAUGHTER. Mr. Chairman, if I may follow up on that?

Mr. NELSON. Surely.

Mr. SLAUGHTER. The reason I asked the question is that some years ago the engineering technicians were in shorter supply in this country than Ph.D.s in science and engineering. I don't know whether you all had the impression that that had been changed, particularly with reference to space contractors and NASA, too.

Mr. EDELSON. It's a situation that I know existed in southern California in the aerospace industry of a few years ago. And since I haven't heard much about it recently, I suspect it's ameliorated somewhat, Mr. Slaughter.

Mr. ALLER. I could comment generally on technician support. We have a lot of that in operational areas, and I think it is pretty much as Dr. Edelson says. It's area-different. For instance, at White Sands we do have some difficulty because of the location with high-quality technician support, and we have a lot of that type of activity there. In some of the areas, for instance, Houston, I don't believe they have that same kind of problem. So I think it is very area-locative.

Mr. SLAUGHTER. Thank you.

Mr. NELSON. OK. Dr. Smith, and then Mr. Clement.

Mr. WILLIAM SMITH. Thank you, Mr. Chairman.

Mr. Nysmith, a general question. Do you think that there is a relationship between the need to revitalize university laboratory equipment and the quality of personnel that might be available to NASA as a result?

Mr. NYSMITH. Well, I am trying to think of whether I want to say "Yes" or "No" to that, because I think there has to be a relationship. I am just not sure of the direct line.

I do think it's critical that the university laboratory equipment be revitalized. I think it's essential to a university's ability to attract the best graduate students particularly, and to do the best research. That's the two purposes, as I view it, of the university graduate schools. So, yes, I guess I would say that there is a direct linkage.

Part of every NASA grant has in it, embedded in it, funding for laboratory equipment. It may well not be enough to solve a university's total problems, but we do make provision, and that is part of it.

Mr. **William Smith**. Thank you.

Dr. Edelson, you spoke of the relationship between your Life Sciences Program and other agency elements with respect to the space station. What specifically would be your strategy for focusing on the critical biological and physical unknowns that might be needed to support our concept of long duration on the space station? What specifically would be the science objectives? And can you accomplish these on a schedule to be compatible with the IOC date?

Mr. **Edelson**. We have a program, Dr. Smith, that addresses itself to that, one that we worked out in conjunction with Mr. Culberston in the Space Station Program office. We're responsible for really two areas. One is to understand the problems associated with long stay-time in orbit, long-time space flight, of the order of months.

Essentially, to answer the question, what is the optimum time to keep people in orbit, obviously, you don't want to keep changing them every week or so, and yet we have serious doubts as to whether they could stay a year or something like that. So is 90 days or 180 days the optimum time, and are there degenerative effects, and are they reversible or not?

We have—and incidentally, this allows me to weave in another theme—exchanged a great deal of information with the Soviet Union in this area, and they have a good deal more experience than we do in this area, which they call bioastronautics.

So we've set up a program to study this. We have established what is called the NASA Space Biological Research Institute, located at the Johnson Space Center, in which we've brought in civil service and outside physicians and biomedical specialists, and we're attacking the problem of human adaptation to space flight on the long-duration basis.

They are interested, and have been interested, in motion sickness because that's been a problem that we've had with the shuttle flights. Although it is becoming clearer now, whereas it's becoming clearer that 50 percent of the people suffer from it—and that seems to hold—it's also clear that it's something that is controllable and only lasts a few days. So after 2 or 3 days or something like that, it's no problem anymore.

There are other problems that we are more worried about, such as bone loss, calcium loss from the bone, fluid shifts in the body—and incidentally, the bone loss leads to osteoporosis, which is—another thought of it is that it could be a good laboratory for the study of osteoporosis, which is a very difficult problem for us nowadays with the aging population, post-menopausal women, and it's becoming something that almost all suffer from osteoporosis.

Mr. **William Smith**. What is it?

Mr. **Edelson**. It's loss of calcium from the bones. The bones get very thin and brittle. And you know, elderly women are all at times subject to breaking bones and cracking their hips and so on and so forth. I am straying a little from the point. But the research that we're doing in this area is to understand space life and the problems of human adaptation to long-time space life.

The other area—and we are, incidentally, deemed to find out a number of ways in which the work that we're doing to adapt to space flight might be very useful to health and benefits here on Earth—we are also responsible for the scientific medical input into the life-support system. We do not provide the engineering to design, but there are problems with development of new space suits for extravehicular activity, for living and working together of 6 or 8 or 10 people over a long period of time in confined, weightless environment and so on. And that requires a lot of biomedical input.

So the simple answer to your question is we have a program aimed at both of those areas, adaptation to space flight and habitability, that we are working on together with the Office of Space Station.

Mr. **Nelson**. Would you get your office to prep our staff on anything you want us to discuss with the Soviets with regard to cooperation in these areas?

Mr. **Edelson**. Yes; I believe, Mr. Chairman, that we have a session scheduled. Art Van Frette has arranged it, and I think it is early in October. And we will be prepared to brief you in detail both from our technical people who have done it and our international people who know a lot more about what they're doing.

I should, just for the record, mention that we do have close cooperation with the Soviet Union in three areas. One of them is the biological area which I just mentioned. The second is the multilateral cooperation involving also the Japanese and the Europeans and the United States and the Soviet Union on the Halley mission. The third area is the search-and-rescue program, where we have good relations.

In fact, we've brought along brochures on each of those today, and I will leave them here. We are prepared to brief you in detail on it at this session. I think it's October 2 or 3.

Mr. **Nelson**. All right, Mr. Clement.

Mr. **Clement**. Thank you, Mr. Chairman.

Mr. Nysmith, I am somewhat concerned about this question of getting engineers and scientists into the Government. Obviously, under the civil service pay scale there is difficulty for the Government to match salaries offered by private industry, and while there are great psychological rewards of being associated with the space program, are we placing ourselves in a position where the Centers can no longer compete with private industry particularly for the best and the brightest of the scientists and the engineers?

Mr. **Nysmith**. Yes; we are approaching that. I think NASA has, because of our mission, been a bit more fortunate than maybe some of the other agencies who do not have that kind of a mission. But I think, looking at NASA as an agency and Dr. Edelson mentioned the situation out at the Ames Research Center in California, Dr. Ballhaus, the Director of that Center is having a terrible problem.

He just cannot hire young people, he can't hire anybody to speak of, and those he has are staying because of the program content and perhaps—well, I shouldn't say he can't hire anybody; he's obviously getting some fresh-outs. They have built some unique capabilities out there, particularly in the computation of fluid dynamics area that will attract a bright young person in that area because that is the center of the universe and on the cutting edge in that particular area. And so that one, perhaps he can compete.

But Dr. Ballhaus has got real problems. That's one specific example. I will broaden that to say that, yes, the problem is one that I think is becoming critical, and it will, I think, get worse and worse if we can't do something about it.

Mr. CLEMENT. Well, for a moment let's compare and contrast two California centers. Let's take Ames and JPL, both NASA centers, slightly different models, Ames being run as a governmental center where you've got to pay on the GS scale, JPL being administered by Cal-Tech and not being locked into the GS scale.

Why don't you tell us the differences between JPL and Ames in competing to get the new starts and also keeping them as they go through their career?

[The information follows:]

Average salary data for JPL and AMES are:

	JPL	AMES
New graduates (B.S.)	$28,548	$23,780
Total S&E staff	47,892	45,777

Mr. NYSMITH. Well, I think that JPL, obviously not being under the civil service system, can offer different—can compete better with the general public or industry as it will. You know, I have not—I am convinced that the Jet Propulsion Laboratory is one of the premier establishments in the country, if not the world, and it's a good model. I am not—and in fact, as I mentioned to the chairman in a previous session, we're looking into the pros and cons of altering some of the facilities along those lines, if not the whole facility, maybe some major parts of it.

It's a difficult thing to do, would be to suddenly make some kind of a transition like that. In fact, I don't think you could do it suddenly. But it may be that the answer to our problem is a transition where we might transition to more Jet Propulsion Laboratory kinds of facilities.

I think one of the key factors in JPL's success is its tight linkage to Cal-Tech, because Cal-Tech is a very dynamic and strong institution and they really manage JPL in a very creative and innovative way.

I think that might be one of the keys, because there are other kinds of local labs, I think, that are not as successful as JPL. So that is a nice model. But they compete better because, yes, they are flexible, they have a well-defined mission within NASA as well. No one really competes with JPL on planetary missions. That is their role in life. So as Dr. Edelson mentioned, the science programs that are needed for the country are put together by the community at large, and if a first priority is a mission that is fixed, if JPL is the laboratory that would do it, then that's what they do. So that works very well.

Mr. **Brown**. Could I make an interjection at that point?

Mr. **Nelson**. Certainly.

Mr. **Brown**. I am relatively close to JPL, and I don't get over there as much as I should. But I observed several years back that they went through a midlife crisis with the declining support for Planetary Exploration Program. They were faced with a very serious problem of maintaining that high-quality staff. They've lost some of them, and they've also diversified their activities so that they're getting considerable DOD support, DOD space programs, which I think is appropriate.

But it has caused some problems, because not all of the Cal-Tech type of people want to work on DOD contracts, and I personally felt that we should have preserved that unique repository of worldwide competence there by maintaining the level of our Planetary Exploration Program such that it would support that operation.

Can you offer any comments as to what that decline in planetary exploration may have done to the mission there and that's had an impact on that?

Mr. **Nysmith**. Well, I will ask Dr. Edelson to comment on a broader front because he is responsible for the management of that center. I will make one comment, which is to say that Dr. Lou Allen, who is the current Director, has made a very specific commitment as to the amount of activity he is willing to devote to activities other than those in support of NASA. So there is a lid.

Mr. **Brown**. You mean Gen. Lou Allen?

Mr. **Nysmith**. Yes; that he has determined that that's the level to which he will do outside-NASA work.

If I could ask Dr. Edelson to comment on the change, because I honestly haven't seen it all that much.

Mr. **Edelson**. Well, I think, Mr. Brown, you're referring to the time in 1980-81——

Mr. **Brown**. Correct.

Mr. **Edelson** [continuing]. When the second ISPM mission was canceled and the VOIR, the Venus orbiting imaging radar, was canceled, and it appeared that the program, Planetary Program, was going down.

OK. Since that time, in addition to my coming in as the institutional AA, a number of things have happened. And let me mention Dr. Allen's coming onboard, who is certainly an outstanding and inspired leader. The Solar System Exploration Committee set forth its strategy and plan, and we picked up on the program and have rejuvenated the Planetary Exploration Program with the VRM and the planetary observer, and we're looking toward the future there.

Second, we've taken on a very large program in Earth-oriented science, in Earth science. So although they are still primarily in planetary science, they also have a major role in Earth science now, and the SIR-A and SIR-B radar flighs and the TOPEX mission and the scatterometer mission which have been assigned to them, are all expected to support their program.

With regard to outside activities, they had a fairly significant amount of work for the Department of Energy, which tailed off.

However, that same volume has been kept up by the Department of Defense, and they have—we have together agreed that that will not be more than 20 percent of the volume.

Mr. BROWN. I wanted to inquire what that percentage was. Is that what you're trying to maintain, and are you?

Mr. EDELSON. Yes, yes; which means that literally they turn away work. They turn away work if it gets over that level.

And also, they turn away any weapons research work. In other words, they will work for the Department of Defense on spacecraft systems and space technology, but not in weapons systems and weapons technology.

Mr. BROWN. Just following up on the question John asked, do you have a figure to compare salary levels for engineers and scientists at JPL with Ames or with the general average?

Mr. NYSMITH. Yes, we can give that to you. I don't have it with me, but we can provide that.

Mr. BROWN. I presume that it is somewhat higher than your general average. Would it be as high as the industry average or above it?

Mr. NYSMITH. I really can't answer that. Let us get that for you.

Mr. BROWN. Yes.

Mr. NYSMITH. We will let you know how it compares.

Mr. BROWN. Yes.

[Information to be supplied follows:]

Average salary data for scientists and engineers are: Ames, $45,777; NASA, $46,595; JPL, $47,892; and industry, $52,397.

Mr. NELSON. We have a number of other questions that we will submit to you in writing.

[Information to be supplied follows:]

Written Questions Submitted by Subcommittee on Space Science and Applications on September 17, 1985, to Mr. Beggs.

QUESTION 1:

The Subcommittee requires specific projections of future programmatic initiatives as a function of budget level. We recognize that your responses cannot be completely accurate but they will be helpful for determining NASA budgetary strategies in the coming years. The Subcommittee will not hold NASA to these preliminary budget projections and this request should be considered for information purposes only.

a. Please provide a ten year forecast (1986-1996) of cost estimates for the programs outlined in the NASA testimony given at the hearing on September 18 and 19. Please include in estimates the programs outlined for the Space Flight, Space Tracking and Data Systems, Space Station, Space Science and Applications. This includes programs in progress and "new starts" NASA expects to begin in the next ten years.

b. Please give estimates for the total NASA budget for each of the next ten fiscal years. These budget estimates should be consistent to support the "new starts" outlined in NASA's testimony.

c. From the budget projections NASA has derived for the next ten years, what would be the impact of a 1 to 2 percent reduction in each budget (i.e., which programs would be slowed; which programs would be maintained; which new starts would be put off; etc.)? In other words, how would NNASA prioritize its programs when faced with budget constraints, yet still maintain a viable American space program?

d. From the budget projections NASA has derived for the next ten years, what would be the impact of a 1 to 2 percent increase in each budget (i.e., which programs would be accelerated; which programs would remain the same; which new starts would begin sooner, etc.)? If given additional resources, above those anticipated, what area would NASA most likely place their emphasis on?

ANSWER A-1:

a. & b. NASA's budget planning process extends for 5 years in the future, thus projected budget runouts for the next 10 years are not available. The attached chart shows our planned budget levels included in the 1986 President's budget as submitted to Congress in January 1985, by major function in each of NASA's four appropriations. The projections for FY 1987 and beyond include a provision for program adjustments and new starts.

c. As we have stated in Congressional testimony before, the specific impacts of a budget reduction will depend on the size of the funding reduction. We will seek to preserve our ongoing

National Aeronautics and Space Administration
FY 1986 BUDGET MULTI-YEAR ESTIMATES
(millions of dollars)

	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990
RESEARCH AND DEVELOPMENT						
Space Transportation System	501.4	709.3	1,184.7	1,725.7	2,563.4	2,765.4
Space Science, Applications & Technology	1,564.8	1,802.3	1,874.3	1,925.9	1,906.8	2,015.4
Supporting Space Activities	14.0	16.2	17.1	18.1	19.0	20.2
Air Transportation	342.4	354.0	368.5	383.6	397.4	410.7
Total R&D	2,422.6	2,881.8	3,444.6	4,053.3	4,886.6	5,211.6
SPACE FLIGHT, CONTROL & DATA COMMUNICATIONS						
Space Transportation Systems	2,806.1	2,701.6	2,085.4	1,727.3	1,790.6	1,850.2
Supporting Space Activities	795.7	808.3	833.0	837.4	850.0	880.2
Total SFCDC	3,601.8	3,509.9	2,918.4	2,564.7	2,641.6	2,730.4
RESEARCH AND PROGRAM MANAGEMENT						
Space Transportation System	563.1	581.2	590.9	603.0	614.5	626.6
Space Science, Applications & Technology	449.0	449.6	462.3	471.0	479.5	488.3
Supporting Space Activities	58.6	59.2	57.9	59.0	60.0	61.1
Air Transportation	265.6	255.0	259.0	263.0	267.0	271.0
Total R&PM	1,336.3	1,345.0	1,370.1	1,396.0	1,421.0	1,447.0
CONSTRUCTION OF FACILITIES						
Space Transportation System	31.2	29.0	25.0	25.0	30.0	35.0
Space Science, Applications & Technology	8.3	13.0	20.0	20.0	20.0	20.0
Supporting Space Activities	85.2	93.3	82.0	82.0	77.0	77.0
Air Transportation	25.3	13.1	20.0	20.0	20.0	15.0
Total CofF	150.0	149.3	147.0	147.0	147.0	147.0
AGENCY TOTALS						
Space Transportation System	3,901.8	4,022.0	3,886.0	4,081.0	4,998.5	5,277.2
Space Science, Applications & Technology	2,021.3	2,264.9	2,356.6	2,416.9	2,406.3	2,523.7
Supporting Space Activities	954.3	977.0	990.0	996.5	1,006.8	1,038.4
Air Transportation	633.3	622.1	647.5	666.6	684.4	696.7
TOTAL	7,510.7	7,886.0	7,880.1	8,161.0	9,096.0	9,536.0

research and analysis activities and those flight projects in which we have made a substantial commitment, as well as the NASA's technical and management capability. We would have to slow down or cancel those programs in which we have not made a substantial commitment, such as OMV, UARS and the Mars Observer.

d. An increase of 1 to 2 percent in funding would enable NASA to undertake new and exciting programs which have been in the planning cycle for many years. Within the funds available, we would initiate those programs for which the plans were the best developed and reflected the overall priorities of the Agency. These priorities are developed during each yearly budget cycle and could include new Space Science and Applications missions (TOPEX, ISTP, CRAF, GP-B), new research thrusts in Aeronautics and Space Technology such as the transatmospheric vehicle and additional capabilities for the Space Transportation System such as the OTV. We would not accelerate any ongoing activities since our planning is already done to optimize the schedules of these projects.

QUESTION A-2:

In planning for Space Station, what type of research does NASA plan on performing to address the psychological and human performance requirements of long duration flight? (In this context, psychological and human performance factors relate to a mental state rather than a physiological condition.)

ANSWER 2:

The Office of Space Station has recognized the significant difference that long duration flights will have in the social and psychological dimensions of crew performance and the consequent implications for effectively meeting customer requirements. Long duration flights coupled to a reliable, user friendly environment, with heterogeneous crews, will demand a greater awareness of the social and psychological components. We fully intend to stress these areas and conduct the research needed to better understand and enhance productivity as well as the means of implementing these requirements.

A research effort has been initiated to develop a coordinated research plan dealing with the social and psychological factors of long duration missions. In 1985, a human productivity contract was granted to a Lockheed/Boeing team to identify productivity requirements, issues, and related research. Part of this contract is dedicated to an examination of organizational, social, and psychological requirements and issues related to crew productivity on long duration flights. The results of this contract will be used in planning further research in this area.

In addition, there are three types of research currently being conducted which are part of this long-term program:

1. Soviet and Analog Research: We are actively engaged in analyzing the social and psychological aspects of the long

duration Soviet flights (the longest being 237 days.) This research focuses upon events and situations that can be tied to social or psychological factors and the success of measures that are used to mitigate problems both during and prior to the flights. We also have an ongoing research program on the social and psychological aspects of analog situations such as those found in the Antarctic, nuclear submarines, oceanographic research vessels, etc.

2. Crew Selection and Training: We have a number of research projects aimed at developing information that will enable us to choose and train people in terms of resistance to performance decrements. One project is directed toward cognitive and perceptual task performance as related to conditions that produce varying degrees of stress. Another project is focused upon core personality dimensions, attitudes, and performance links in work, life, and team situations. Further research planned includes the refinement of performance evaluation methodology, continued evaluation and validation of crew selection criteria, personality, crew coordination, performance relationships, training evaluation, and work group composition relationships. One goal is to develop a model which can relate variables involved in crew performance, and crew interaction in order to develop an integrated set of methodologies for crew selection, training, organization, and techniques to remedy performance degradation in the Space Station environment.

3. Habitability and Crew Performance: These research projects are looking at the effects of various aspects of the physical environment to understand their impact on crew morale, motivation, attention, fatigue, stress, behavior, and performance. Current research covers crew behaviors as they are affected by interior architecture, and the effect of various interior designs upon vigilance, fatigue, and performance.

QUESTION A-3:

For the initial Space Station operating capability for power, how will the 75 kw be allocated among international users, other commercial users, science and station keeping and other internal requirements? What criteria or algorithms will be used for the allocation?

ANSWER A-3:

The Space Station reference configuration described in the Phase B Request for Proposal stated that a total of 75 kw would be available of which 25 kw would be necessary to support the manned element housekeeping, including support to station keeping, and the remaining 50 kw would be available to users on the manned element. This basic allocation is now being further studied in Phase B, with a more definitive answer not anticipated until the configuration is baselined in the early spring of 1986. We are working during Phase B to determine a method of allocation among users including all of the international partners in the Space Station Program which will permit changing complements of users and changing user emphases during the life of the Space Station. We have just started discussions with the various user communities, both within the United States and in the countries of our international partners, to develop satisfactory approaches for allocation of resources, including power, and will not have specific criteria or algorithms for some time.

QUESTION A-4:

Please provide information on the number of sounding rocket payloads funded by NASA from 1980 to the present and the number of Spartan payloads flow thus far and the projected yearly rate for both rockets and Spartan flights up to 1990.

ANSWER A-4:

The number of sounding rocket payloads funded by NASA from FY 1980 through FY 1985 are as follows:

FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
49	46	41	51	39	37

The number of sounding rocket flights projected on a yearly rate up to 1990 are as follows:

FY 1986	FY 1987	FY 1988	FY 1989	FY 1990
44	43	43	40	37

One Spartan payload has been flown to date. This was Spartan 1 a high energy x-ray experiment which mapped the x-ray emissions from the center of the Milky Way galaxy and several sources in the Perseus cluster of galaxies. The experiment was successfully flown on the STS-51G mission, which was launched in June of 1985.

The present schedule calls for launching two Spartans in calendar year 1986, two in 1987, three in 1988, and four in 1989.

QUESTION A-5:

For the years 1975-1985 please provide by year the percent of OSSA's Research and Analysis budget for solar terrestrial programs and the percent for the remaining planetary exploration, physics and astronomy, applications, life sciences, and microgravity research programs. For this analysis, assume that solar terrestrial programs include the Solar Optical Telescope, International Solar Terrestrial Physics Program, Ulysses, Solar Polar Orbiter, Solar Terrestrial Observatory, and those space plasma physics experiments on spacelab flight.

ANSWER A-5:

An analysis of the percentage of R&A in the solar terrestrial programs will be provided upon completion of calculation. It is anticipated that the information will be provided by mid-December.

QUESTION A-6:

As the manpower requirements for the Galileo mission decline, to what programs will the Jet Propulsion Laboratory personnel be assigned?

ANSWER A-6:

As The Galileo manpower requirements decline, the plan has been to:

a. transfer the appropriate members of the spacecraft development team to the Comet Rendezvous/Asteroid Flyby (CRAF) pre-project activity; and,

b. assign the remaining team members to other interim tasks such as science instruments, advanced development tasks and for sponsors other than NASA.

With an appropriate level of Advanced Technical Development (ATD) funding in FY 1986 and 1987 and support for an FY 1988 new start of the Mariner Mark II (MMII) Program, it will be possible to deploy the Galileo personnel in a manner that will provide for the development capability when needed to implement the CRAF and subsequent Mariner Mark II missions.

QUESTION A-7:

If the Comet Rendezvous/Asteroid Flyby mission does not receive a new start in FY 1987, how can the program be reconfigured to achieve the same science goals as would be the case with an FY 1987 new start?

ANSWER A-7:

A pre-perihelion rendezvous with the Comet Tempel 2 was identified as the next comet mission option if the Wild 2 opportunity recommended for the FY 1987 new start did not materialize. The science value of a Tempel 2 mission is expected to be similar to that of Wild 2 and has equivalent science interest within the science community. The September 1992 launch to Tempel 2 utilizes a Delta V-EGA trajectory and results in a rendezvous with the comet in December 1996, approximately two years later than that planned for Wild 2. The Tempel 2 perihelion would occur in October 1999, approximately 1,000 days after initial rendezvous. The required post-launch Delta-V is significantly higher than needed for the Wild 2 1991 mission. This will be provided by increasing the propellant capacity of the propulsion system which will be provided by the Federal Republic of Germany. This increased capacity propulsion system has direct application to the later MMII missions (as does the entire MMII spacecraft).

QUESTION A-8:

What would be the near-term budgetary savings if NASA terminated the Pioneer Venus Orbiter data acquisition program?

ANSWER A-8:

Near-term savings from turning off the Pioneer Venus Orbiter spacecraft on January 1, 1986, would be approximately $1.8 million in FY 1986 and $2.7 million in FY 1987. These numbers assume that the Pioneer Venus scientists will be supported during both FY 1986 and 1987 to complete the reduction, analysis, and archiving of previously acquired data.

QUESTION A-9:

What further technical achievements and what budgetary commitments are needed for the AXAF optics program in order to support a new start in FY 1988 with a low degree of technical risk.

ANSWER A-9:

Technical risk of the AXAF program can be further reduced by continued analysis of the Technology Mirror Assembly (TMA) data. Recent tests of the TMA optical system have isolated and defined a problem on meeting the TMA goal for encircle energy. Options for dealing with the problem (which may include further work on the TMA) and the associated budgetary requirements are being developed. This work, as well as the planned continued definition work on the high resolution mirror assembly, the aspects determination system, and the Science Instruments, will support a new start for AXAF in FY 1988 with a low degree of technical risk.

QUESTION A-10:

During testimony, NASA witnesses suggested that the second generation shuttle and the advanced Earth-to-orbit vehicle may be combined, yet the separately depicted milestones differ by a decade. If these programs were combined, what would be the equivalent milestone?

ANSWER A-10:

It is probably misleading to speak of the advanced Earth-to-orbit vehicle. More than one advanced launch vehicle may be needed between now and 2010. That is the timeframe of the joint architecture studies now underway, and predictions as to the outcome of these studies would be premature. However, one likely scenario that has been discussed would include an advanced manned rocket vehicle, i.e., a second-generation shuttle, about 2002, and a larger, unmanned cargo vehicle somewhat earlier, if mission and economic analyses support it. Air-breathing technology would likely not be available until later, and may be viewed as a candidate for a third generation STS, unless the need date slipped to 2010 or so or the technology matures considerably more rapidly than now foreseen.

QUESTION A-11:

With regard to the Deep Space Tracking Network, would a tracking station located in the Soviet Union substantially enhance the sensitivity or coverage as compared to the current system?

ANSWER A-11:

No, a station in the Soviet Union would not substantially enhance the Deep Space Network capability. The basic geographical needs are three stations, approximately 120 degrees apart around the Earth, to permit continuous coverage of any point in deep space. Also, at least one station must be in each hemisphere to provide a north-south baseline for determining direction to a spacecraft. Our present configuration satisfies these needs.

QUESTION A-12:

What improvements will be made in the TDRS follow-on system to accommodate high data rate users such as Space Station, remote sensing, and the Space Telescope?

ANSWER A-12:

Future plans to augment the space network consist of additional satellites, TDRS 7-9, and a second ground terminal. These proposals will keep the network operating through the 1990's.

The proposed second ground terminal will allow the addition of two more operational satellites to the TDRS constellation which will increase the network support capacity for high rate, single access users with data rates as high as 300 megabits per second. The follow-on satellites will be functionally the same as the current models but will include applicable technology improvements.

QUESTION A-13:

What, if any, technologies developed as part of the ACTS program will be used in the development of the follow-on TDRSS ?

ANSWER A-13:

Technologies being developed as part of the ACTS program will be evaluated and used as appropriate in the Advanced Tracking and Data Relay Satellite anticipated in the year 2000 time period. Of particular interest will be the Ka-Band and optical frequency experiments.

QUESTION A-14:

What tangible benefits will the upcoming teacher-in-space mission have for teaching profession? For the space program?

ANSWER A-14:

The selection of a teacher as the first opportunity for the Space Flight Participant Program has already resulted in significant benefits to the public, to the teaching profession, and to the space program.

The selection process itself stimulated the interest of 44,000 teachers who requested the application packet. This interest generated considerable media attention for the individual teachers who applied, as well as for the Space Transportation System. It presented an opportunity for teachers to receive recognition for their efforts in the classroom and to elaborate on innovative methods for which they use the space program as a motivating tool for their students.

Of those who requested the entry materials, 11,000 teachers completed the challenging application packet to enter the selection process. Many candidates reported that they spent as many as 150 hours to complete the thought provoking essay questions. NASA's Educational Affairs Division at Headquarters, and the Education Program offices at the Field Centers have maintained contact with these 11,000 teachers to distribute educational materials for the classroom and inform them of other opportunities for involvement. Through this process, NASA is able to develop a network of motivated teachers who will help inspire the next generation of scientists and engineers who will be needed to maintain the Nation's leadership role in aeronautics and astronautics.

The 114 state nominees were appointed as "Space Ambassadors" and have been asked to work with their state education agencies to serve as expert consultants to develop teaching materials and activities to promote enhanced student understanding of science and technology. The activities in which the Space Ambassadors participated, during the National Awards Program, enabled them to become the most knowledgeable teachers in the country about the space program and how to relate that information to students.

The 10 finalists have also been given special roles as part of the Teacher in Space Project. The 8 individuals who did not achieve primary or backup candidate status are now working for one year at NASA Field Centers to assist in the development of curriculum materials and be available as speakers for educational workshops and conferences throughout the country. They will then return to the classroom with the benefit of an extra-ordinary experience that should prove invaluable to their teaching careers.

Perhaps the most visible benefits of the Teacher in Space Project will result from Christa McAuliffe's actual participation on a Space Shuttle mission. Certainly the attention of millions of students and teachers will be focused upon this flight. To provide substance to the excitement, numerous course activities will emerge through Christa's participation. Both live broadcast and filmed events are scheduled to take place, including the first "classroom in space" lecture. The lecture will be transmitted via satellite and be able to be viewed in classes throughout the world. A "Mission Watch" program, hosted by backup candidate Barbara Morgan will also be broadcasted live from the Johnson Space Center and will provide students with an opportunity to call in questions to mission scientists and engineers.

Upon the return from the orbiting field trip, Christa and Barbara will work full-time for NASA until the beginning of the new school year. In her role as space veteran, Christa will travel extensively throughout the country to share the experience of space flight with students and teachers. Already, letters from organizations at the local, state, and national level have arrived at NASA requesting Christa's participation as a speaker for their conferences and meetings. It is also expected that an ambitious schedule of newspaper, television, and radio interviews will be undertaken.

In a speech before a recent education convention, Christa remarked, "I touch the future I teach." Through the Teacher in Space Project, NASA believes she will touch the lives of millions of students and teachers throughout the country. The project has already provided a positive focal point for education nationwide and continues daily to serve as a fine example of the outstanding aspects of our educational system. It is this spirit combined with the commitment and creativity each teacher brought to this historic event that contributes to the increased recognition of teachers in our country.

Mr. **Brown**. May I just ask one followup question?

Mr. **Nelson**. Certainly.

Mr. **Brown**. The purpose of these hearings has been to focus on your strategic planning. May I say, as one who has been interested in strategic planning for quite a few years, that I perceive an enhanced quality of planning taking place here. It's a difficult thing to do, and of course, it involves several things, such as your agency mission and goals being clearly defined so that you can plan to achieve them. And we don't always have that. Of course, we hope that the new commission will help in this.

Second, it involves your level of resources, which is going to be quite restrictive, and I am interested in knowing—and you may better supply this for the record—what has been the impact of the fact that, according to the Administrator.

We thought we had a commitment for a 1-percent real growth rate in NASA and that gives you one baseline for planning. The action taken by the Congress has been below that this year. I don't know what the final figure will be, but it probably will not be that; it may be substantially less than that if we stick with the current-year dollar levels, you may be 4 percent below the 1-percent real growth.

What would it take in terms of resources to impact the kind of schedules that you have set forth, Dr. Edelson? In other words, if you had, say, 2 percent real growth or 3 percent real growth, what would it do to the programs that you list in development? Would it speed them up 1 year, 2 years, and so forth?

I assume that you have in some place in the organization done those kinds of projections, and I think from the standpoint of this subcommittee and the Congress we need to know what the decisions that the Congress makes, how it impacts upon these long-range plans that you're making, so that we can determine in some realistic fashion that if you get *x* percent growth versus *y* percent growth, what it does to these projects that we're interested in.

There is a number here that I am interested in, as you know, and I would like to know how they're impacted by these different scenarios.

Could something like that be provided to the committee? I know I have been a little hazy, but I think you understand what I have said.

Mr. **Nelson**. No; I don't think you're being hazy at all. I think you have been very clear, and the question is an excellent one.

I would like you to provide that to the committee.

Mr. **Edelson**. We will do that, sir.

[Information to be supplied follows:]

NASA
National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of C:DBD:C17065f

Dr. Rad Byerly
Staff Director
Subcommittee on Space Science
and Applications
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Rad:

Enclosed is the material for the record requested on page 97 of Dr. Edelson's transcript by Representative Brown during the hearing on September 19, 1985.

This material completes the information requested during that hearing.

Sincerely,

Lyn W. Heninger

Lynn W. Heninger
Acting, Director
Congressional Liaison Division

Enclosure

Material requested for the record on page 97, line 2197, by Representative Brown on September 19, 1985.

Increased funding would permit NASA to undertake additional new and exciting programs beyond those contained in our current budget. Among the most promising of these new flight projects are the Ocean Topography Experiment (TOPEX), the International Solar Terrestrial Physics Program (ISTP), the Comet Rendezvous/Asteroid Flyby (CRAF), and the Advanced X-Ray Astrophysics Facility (AXAF) program.

The TOPEX mission provides a basis for improving our understanding of the general circulation of the global oceans. When combined with scatterometer wind data from the NASA Scatterometer (NSCAT) to be flown on the Navy Remote Ocean Sensing System (N-ROSS) in 1990, a unique, never-before-seen, view of the oceans' driving force (winds) and the resulting ocean response (topography) would be obtained. Such a view of the global oceans could provide a fundamental breakthrough in improving our understanding of the oceans' role in climate variability.

The ISTP represents a unique opportunity to conduct a coordinated series of measurements required to better understand the flow of energy and matter from the Sun to the Earth. ISTP guarantees continued U.S. leadership in solar-terrestrial research while capitalizing on the leverage provided by international collaboration with Europe and Japan. U.S. instruments would be carried on six missions with full access to the program data base while only three of the six spacecraft for these missions would be continued by NASA.

The CRAF mission would obtain a comprehensive range of detailed scientific data about two of the least-studied objects in the solar system: comets and asteroids. This data would expand our basic knowledge about the solar system--its origin, earliest history, and evolution. The results of this mission could have a major impact on our understanding of several important scientific questions, including the nature and source of the material that formed the solar system and the origin of life on Earth.

AXAF is a powerful x-ray observatory which would permit scientists to peer deeply into the universe to study astronomical objects. Since x-ray observations are particularly sensitive to violent events and their aftermaths, AXAF would provide a powerful astronomical observatory for exploring the nature of cosmic events of central importance to understanding the origin and evolution of the universe. AXAF would address such fundamental questions as the nature of celestial phenomena such as black holes and quasars, the nature of physical processes which take place in and between astronomical objects, and the evolution of the universe.

These future flight projects, as well as others, will play a key role in the future of the Space Science and Applications program, and are serious candidates for initiation in the next few years if sufficient resources can be obtained.

In response to your specific question about what new programs could be initiated if available resources were increased by one to four percent per year, we would propose to accelerate the initiation of development of the same programs as are currently planned. The science advisory committees have strongly recommended that NASA initiate development of TOPEX, ISTP, CRAF, and AXAF before we consider other major flight initiatives. OSSA agrees that these are currently our most important new starts, therefore, depending on the funding available and the project schedules, we would initiate these projects as rapidly as possible. We would then accelerate the future new starts and build the necessary research and operations capabilities to effectively support the expanded program.

We would clearly be able to work through the planning queue much more quickly with a 4 percent per year increase in our overall budget. We have invested much effort in defining these new missions and are looking forward to initiating them as rapidly as our resources will allow.

Mr. **Brown**. I will defer all the other fascinating questions. [Laughter.]

Mr. **Nelson**. Anybody else?

[No response.]

Mr. **Nelson**. Do any of you all have any questions for each other? [Laughter.]

Mr. **Nysmith**. We ask those all the time. [Laughter.]

Mr. **Nelson**. All right. Thank you. It's been an excellent hearing.

Mr. **Nysmith**. Thank you.

Mr. **Edelson**. Thank you.

Mr. **Aller**. Thank you.

Mr. **Nelson**. The meeting is adjourned.

Thank you.

[Whereupon, at 12:04 p.m., the subcommittee was adjourned.]

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APPENDIX

NASA
National Aeronautics and
Space Administration
Washington, D.C.
20546

OCT 15 1985

Reply to Attn of: C:DBD:C17049

Honorable Don Fuqua
Chairman
Committee on Science
and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

It is requested that the following correction be included in the hearing record resulting from the September 17, 1985, hearing at which Mr. Beggs testified on NASA Long-Range Planning:

Page	Line(s)	Proposed Wording
18	407-412	At that time in '65, I think NASA was spending something like 3 percent of the Federal budget, which would have been in the order of maybe seven-tenths or eight-tenths of 1 percent of the GNP. Today we spend eight-tenths of 1 percent of the Federal budget, which is two-tenths of 1 percent of the GNP on space.

We understand that this letter may be inserted in the transcript in the form of an appendix and referred to by footnote in the main text.

Sincerely,

Lynn W. Heninger
Acting, Director
Congressional Liaison Division